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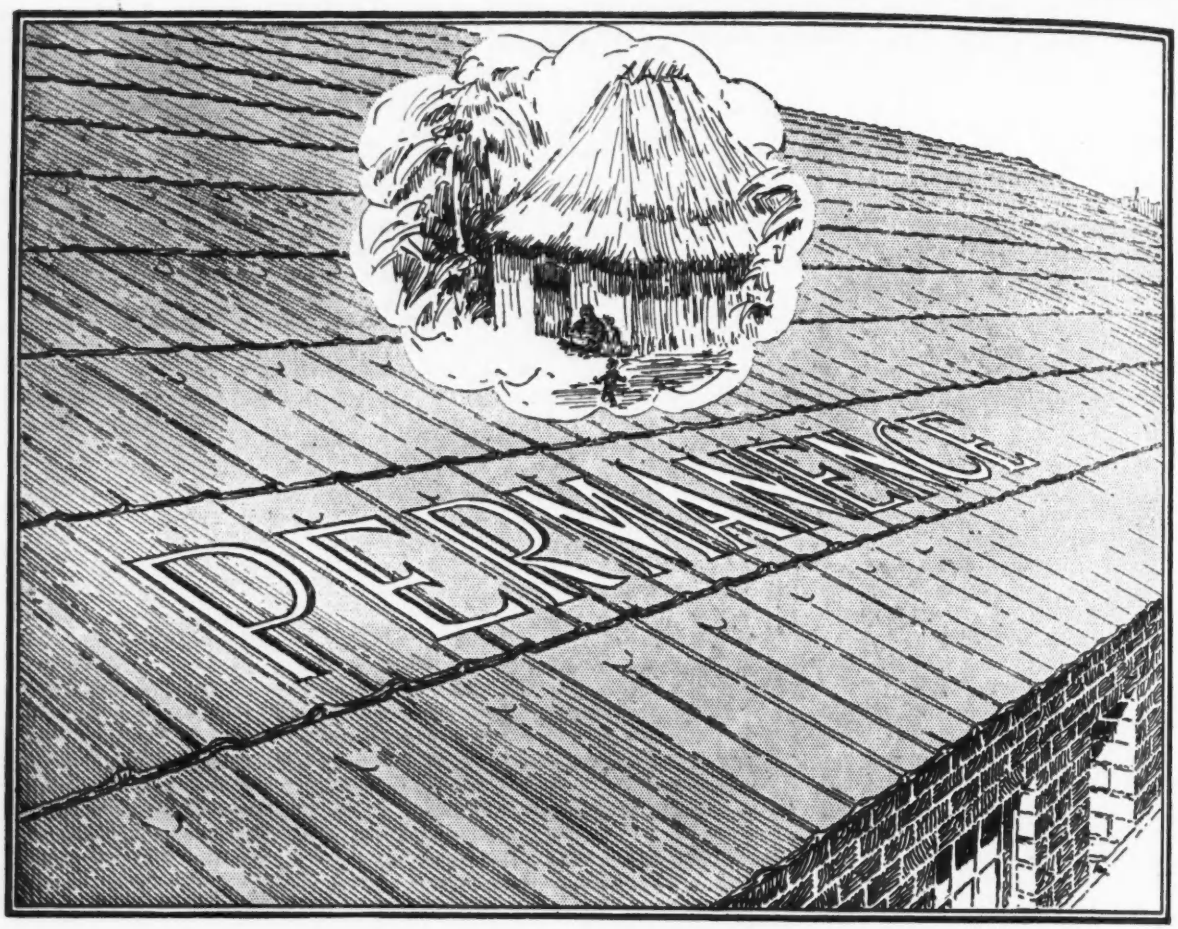
IN TWO SECTIONS

SECTION ONE



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DEVOTED TO CIVIL ENGINEERING AND CONTRACTING

FRANK C. WIGHT
Editor

Volume 92 — NEW YORK, APRIL 17, 1924 — Number 16

From the Vantage Point of Fifty Years

FIFTY years is a variable quantity. It is the major part of a man's life, an era for a nation, a passing moment in geology. For a magazine it is a ripe and venerable age. Few journals in this country, and fewer technical journals, have reached it. *Engineering News-Record,* therefore, takes pride in coming, in full vigor and health, to its fiftieth birthday. By long custom, the accomplishment of fifty years has been an occasion for celebration. Kings and queens hold jubilees when by rare chance they reign that long; cities stage semi-centennials, and married folk a golden wedding. *Engineering News-Record* celebrates by this issue.

Because the whole of the fifty years of this journalistic life has been devoted to the service of the civil engineering profession and to the record of the things that profession and its allies have accomplished, it has been thought fitting to pause in the weekly record of things done and of ways to do them and look back over the half-century of civil engineering and construction which has just passed. Engineers by nature are not apt to set much store by the past; theirs is a forward-looking profession, with its major concerns in the living present. The day's work looms over large, and precedent, instead of being the governor of the future as in the law, is merely the starting place from which to move ahead. But, while no one knows what lies around the turn in an as yet untraveled road, the going will be made easier by the knowledge of how the curves and grades behind were negotiated.

This issue of *Engineering News-Record* does not pretend to be a complete digest of the past fifty years of civil engineering, but it does give, through the eyes of some of the most distinguished of those who have made engineering in these years, a picture of whence we came and of some of the landmarks in the coming, and from that picture some idea may be gained of the topography of the way we are bound.

AT any given time since man has kept records there were probably those who marveled at the material progress of the preceding half-century. From our present vantage point there seem to be long periods when no progress was made, but scales change with the years and we have no fit measure of the rising slope of the curve of the past.

The curve today is moving more steeply upward and its slope is more apparent. We have come far in the past fifty years. Electricity, as a servant of man, has been born and grown to giant stature, and with it have come power production, distribution and utilization and the marvels of telephony and its mysterious step-sister radio. Oil derivatives and the gasoline engine have made possible the automobile, the insoluble problem of flying has been solved, and men go under the sea in ships. Science has found new and useful elements and has isolated and defeated a few of the unfriendly germs. We live longer, we live more intensely and, in spite of the pessimists who lament the good old days, more of us live more happily than we did fifty years ago.

It would have been possible to have devoted this issue to the contributions the engineer has made to this changed world, but that has been done many times before. Instead, the purpose in these pages is to recite the changes in the practice of engineering. The

contributors were asked to go up, figuratively, on a hilltop and look back over the past half-century and to see where there were sharp changes in the curves of progress and point out not only what those changes were but why they were and what relation they bore to possible changes in the future. This, we think, they have admirably done.

THESE reviews make clear one fact. The development in the field of civil engineering and construction has not been due to any epoch making discovery. There has been no invention or device that has revolutionized practice as the steam engine revolutionized industry the century before. More radically new things appeared in the world in this half-century than in any other before and they have contributed to make the world a different sort of place, but civil engineering design and construction did not change because of them except to adapt them to its uses and to adapt itself to the changes these new things wrought.

People became crowded more and more in our cities so the services they needed increased and the difficulties of supplying those services, and even of making city life worth living, became more difficult. Travel became a national habit and the factory and the farm got farther and farther away from those who use their products, so the demands of transportation fast outgrew the supply. Industry multiplied and with it the need for the structures to house it. All of these changes put new and greater obligations on the civil engineer.

To meet these increasing demands he did not radically revise his theory or seek any new natural force, but he did apply to his practice the new things that he learned. He acquired improved materials—portland cement instead of natural, steel instead of wrought iron, better and more of the minor materials such as asphalt, paint, clay tile and the cement products. He accepted and assisted in an enormous improvement and extension of the mechanical aids to construction. He simplified his details and reduced his sections as the widening science of testing taught him more and more about the materials he was using and made more precise his analysis of the stresses those materials would stand. He adapted the new biological knowledge to the purification of water and of sewage. He went ahead with his electrical brother in the improvement of the structures and machines which produce electrical energy from falling water. He had continually to devise new ways of doing things. Ingenuity—the root word of his name—was his lode star.

That ingenuity explains why the engineer has been able not only to fit himself to the changing world, but also to contribute so much to that change. It denotes a flexibility of mind which has been necessary for a solution of material problems and which has promised to be a most useful talent in solving some of the social and economic problems of the future. If any pessimistic note were to be included in this record of the past it would be that the quality expressed by the term ingenuity is not now so dominant in civil engineers as it was in the half-century we are reviewing.

Let the reader consider the clear reconstruction of the past fifty years of engineering in the series of short reminiscences by twenty-four veteran engineers that follow these pages. The elder statesmen have seen the writing on the wall. The expression is individual but a definite strain runs through the whole composition. Increase in size has been the great development; our progress has been mainly in the greater facility with which we can execute work due to the omnipresence of machinery; the fundamentals are the same today as yesterday—these are observations that we can all make. But there are other and more important ones; individualism is passing, they say; we are becoming overstandardized; and in our worship of theory, or recorded data, we are losing that independence of thought that should characterize growth.

A TRADE is standardized; each man in it is as good as the next one and the things to do are all learned when one steps up out of apprenticeship. The distinguishing feature of the professional man should be a constant self education and an independence of thought. That distinction the civil engineer has had. If he loses it and merges himself altogether in the common practice of his group he descends to the level of the journeyman, whose only distinction from his fellow is in skill.

There is no danger of the profession of civil engineering forgetting the mechanics of its art or of its ever becoming less necessary to the world. But there is some danger of its becoming complacent, of its losing its ingenuity. It can overemphasize the rules by which it works and so deaden the imagination and initiative of its members that they become high grade automatons following blindly the rules set down by book, or committee or law. And in so doing there will be lost the great opportunity that the next fifty years offers the engineer, the opportunity to contribute to social and economic reform that respect for basic truth and the undeviating deduction from the truth that the past training and practice of the engineer make him so well able to supply.

It has been a marvelous fifty years. The engineer has contributed more than his share of the marvels but in so doing he has learned how better to serve the coming half-century. If the pages of this issue remind the engineer of today what he owes the past and give him some idea how to utilize that past to better the future, its purpose will have been accomplished.

SHORT of an encyclopedic volume the review in these pages of the fifty years of civil engineering and construction could not be complete. Each of the authors had space only to touch the major facts in his own retrospect and several of the fields for various reasons could not be treated at all. Concrete, for instance, is universal and its development is a part of the development of every field of engineering described. Rivers and harbors have really changed very little in the past fifty years except in the construction operations, which changes are common to all fields. Irrigation has been so thoroughly treated in the recent numbers of this journal that anything now would be too early repetition. Surveying, except for instrumental development and the advent of the airplane, has but little now to offer. The subjects which are covered, on the other hand, encompass the major part of the field of civil engineering construction. To comment on them is unnecessary; they speak for themselves. But in order to make the record complete and to certify to the authority of the engineers who have consented to contribute to this issue there is appended a brief biographical record of each of the contributors of the major articles. Each reminiscence article carries its own biography.

GUSTAV LINDENTHAL

One of the most noted of bridge engineers; designer and builder of many railroad bridges in Pennsylvania, Ohio, West Virginia, Illinois, Indiana; designer of Hell Gate bridge over East River at New York and for a time Commissioner of Bridges of New York City; chief engineer, North River Bridge Co. which proposes to bridge Hudson River at New York City.

CHARLES T. MAIN

Consulting engineer, engineer and designer of industrial plants; has designed, constructed and equipped many textile mills, industrial plants and steam and water power installations, etc., principally in New England; past-president of A.S.M.E.

FREDERICK L. CRANFORD

A contractor son of a contractor father and himself a dean of the profession; builder of much of the original subway in New York; president, Associated General Contractors of America.

ROBERT FLETCHER

Director-emeritus, Thayer School of Civil Engineering, Dartmouth; since 1871 connected with that university, being organizer of Thayer School; prominent in water-works field as designer and engineer-in-charge of construction of Hanover, N. H., system.

DANIEL E. MORAN

Consulting engineer on foundation work and one who perhaps knows more of subsurface conditions in Manhattan, New York, than any other man; former vice-president and present consulting engineer, Foundation Co., which he assisted in organizing; inventor of Moran lock and other appliances for pneumatic caisson work.

J. VIPOND DAVIES

Consultant in tunnel work of international reputation; long connected with subaqueous tunnel construction around New York City; constructing engineer of 18 miles of aqueduct tunnels in Mexico; one of three engineers who originally reported on Moffat Tunnel project and now consulting engineer on that project.

C. S. HILL

In technical editorial work for 35 years; joined *Engineering News-Record* in 1888; with *Engineering and Contracting* for 10 years as managing editor; editor of *The Contractor;* since 1918 associate editor of *Engineering News-Record.*

HENRY K. WICKSTEED

Pioneer railroad location engineer; now with Canadian Railway lines; for many years one of the most prominent figures in development of Canada's railroad systems.

HENRY J. BURT

Civil engineer for Holabird and Roche, architects, Chicago; designer of structure for many of Chicago's high buildings; for ten years with American Bridge Co.; author of book on steel building construction.

JOHN D. GALLOWAY

One of California's most noted engineers; designer and builder of many of the principal skyscrapers in San Francisco prior to the earthquake; prominent in hydro-electric work both in design of dams and of power houses and transmission lines.

M. N. BAKER

For 36 years associate editor of *Engineering News-Record* and its predecessor, *Engineering News;* editor, Manual of American Water-Works; author of many books and treatises on water-works, sewage disposal and purification and general municipal subjects.

ALLEN HAZEN

Eminent in the water-supply field; in charge of Lawrence experiment station; in private practice in Boston with Albert F. Noyes and in New York; in 1903 went into partnership with George C. Whipple.

HARRISON P. EDDY

Consulting civil and sanitary engineer; chemist sewage-works and superintendent of sewers at Worcester for many years; member of Metcalf & Eddy, Boston; specialist in sewerage and the treatment of sewage and industrial wastes; joint author with Leonard Metcalf of "American Sewerage Practice."

WILLIAM HOOD

One of the West's best known railroad civil engineers; until his retirement in 1921, chief engineer for 21 years of the Southern Pacific Co.; railway service dates from 1867.

FRANCIS C. SHENEHON

Consulting hydraulic engineer, Minneapolis, Minn.; vice-president and general manager of construction. Byllesby Engineering and Management Corp.; long principal assistant U. S. engineer on the Great Lakes and for eight years dean of engineering, University of Minnesota.

Engineering Today and Yesterday

A Composite View

TO EACH of the men whose names head the brief articles below was put the question, "What is the essential difference you remark between engineering of today and engineering when you started practice?" Every one of these men has been engaged in engineering or construction work for the major part of the fifty years this issue of *Engineering News-Record* is commemorating. Their replies furnish an admirable picture of the intangibles of the development in this half-century, the tangible evidences of which are specifically set forth in the surveys of developments in the major branches of engineering which make up the greater part of this issue.

HENRY G. PROUT

Engineer and business executive, Editor of the "Railroad Gazette," soldier in the Civil War and in Egypt

SHADES of Frost and Stauffer and Wellington, I salute ye! As ye look down from the further stars think kindly of the ancient days, of the rivalries and the constant friendliness! Your successors ask me to say a word about the essential difference between engineering then and now.

Fifty-five years ago this month, while a sophomore in civil engineering, I began field work in geodesy and astronomy on the Survey of the Great Lakes. It seems to me that there is no essential difference in engineers and engineering from that day to this. That calls for a definition or two. "Essential: Of, constituting, a thing's essence." "Essence: Reality underlying phenomena." The essence of engineering is the seeing eye and the contriving mind; the instinct for the relations of space and time, force and matter. These things are heaven-born; they cannot be given but they can be trained if they are there. Teachers know well the tragedy of trying to make engineers of boys who have not the gifts. Indeed, a search for the essential would carry us back to the pre-historic engineers who taught the Cro-Magnons to use bows and arrows. They had the seeing eye and the contriving mind. They developed inevitably into the men who built Big Bertha. The difference is not essential.

Those records of experience which we call laws of nature settle down into principles which don't change in fifty years. The engineering schools existing fifty years ago were scant of money and of laboratories and shops. In poverty they bred philosophers and not artisans. Men whose imagination and powers of analysis and reason were trained in severe study of abstract principles became self-reliant and original. It is not impossible that those elder engineers were more firmly grounded than the modern graduates.

Fifty years ago the engineers of America were mostly absorbed by the railroads and the things that go with railroads—rolling stock, machinery and bridges. The structural engineer began to emerge—a process considerably stimulated by the destruction of Chicago. We had developed a few fine hydraulic and mill engineers and a good many mining engineers. Sanitary engineering and highway engineering hardly existed in this country notwithstanding the ancient examples of Rome and England and France. Railroading with its allies, was the one great field. We worked under new conditions. Dear money, dear labor, vast unpeopled areas, immense distances, great rivers and mountains and freedom from bureaucrats brought out a race of engineers not seen since the days of Julius Caesar. They were daring, enterprising and fertile. They surprised Europe with grades and curves, with swinging trucks and flexible locomotives. They scared Europe with pin-connected trusses.

The engineer of today knows many more things than the engineer of fifty years ago. He has more physics, metallurgy and chemistry and even mathematics. I mean, of course, the average engineer. I am not thinking of the new knowledge, but of the wider diffusion of the old knowledge. No abler mathematicians or physicists are graduated today, but there are more of them, absolutely and relatively.

The engineer of today, with his new knowledge and with the broadcasting of the old knowledge, has more opportunities than the engineers of fifty years ago, and with those opportunities have come new responsibilities. The engineer of the future will face ever-growing opportunities and responsibilities. He will touch mankind in more and more ways and places. His discipline is rare and precious, for nature stands always at his side. It seems worth while to stop sometimes and reflect upon his duties and his destiny.

WILLARD BEAHAN

A railroad location and construction engineer since 1880; a leader in the broader view of the engineer

THE ESSENTIAL difference between engineering of today and engineering when I started to practice forty-five years ago is that it is more human. It now has more to do with men without having less to do with mathematics. Engineers now have in their minds the desire to strive to see what service they can render rather than to show what they can build. We strive for "that gratifying feeling that our duty has been done."

Forty-five years ago we strove to be engineers. We saw nothing else, thought of nothing else. To become chief engineer, to have a permanent position as such at a good salary satisfied us and was our *ne plus ultra*. We took all our time to be or to become engineers and took no time nor effort to be men or citizens. We were narrow, provincial and uninspiring to the younger men. We were star players but not team workers. The men of my time then were very lame in that regard. As railroad civil engineers of that time we were almost exclusively employed on railroad location and construction. We were czars. We turned over that new line in about fifty mile sections to the operating department. Up to that time we were "monarch of all we surveyed." When new construction quite ceased some time later, if we were retained on that road we had no sympathy with the work of the roadmaster or the division superintendent and were therefore of little use to the president. The men of my time usually made

this sad mistake. The result is they died chief engineers; often with much of their natural duties delegated to engineers of maintenance-of-way of railroads.

Younger classes from our colleges are doing better. They are better mixers. Football and glee clubs have helped them. They are broader in thought and vision and far less clannish. They are more conspicuous as members of the human race.

During the working years of my life, this country has shown tremendous growth in transportation and in industrial and technical development. All this is engineering work. The result is that engineers are much more prominent in business and in society in its broad sense.

We are today trying more to render service to our race; to "produce the goods" for our time and to be remembered for what we gave to the world.

JOHN F. O'ROURKE

Engineer and Contractor. Long experienced in heavy construction operations, from the Poughkeepsie Bridge in the eighties to the subways of today

ENGINEERING in the Seventies was confused with surveying in most people's minds. A city surveyor in New York City was an engineer authorized by the Board of Aldermen to take charge of city improvement, receiving 5 per cent of the cost of such contracts as were given him to look after. Regulating, grading, paving, and sewer construction were practically all that the city was doing at that time, for which he attended to the lines, grades and estimates; his final certificate entitling the contractor to his final payment was itself final. The more important city surveyors had large field and office organizations and their annual fees went into six figures.

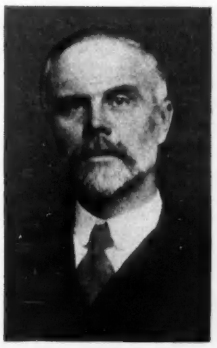
My engineering practice began as a student in the office of Edward Boyle, a city surveyor. He was popular at City Hall and had many of the largest contracts in his charge, such as grading Eighth Ave. from 59th to 125th St., an immense fill most of the way. He also did the engineering on most of the big street openings and widenings. These things required the most accurate surveying and the hundreds of damage and benefit maps needed were plotted, lettered and colored by draftsmen who were real artists in that line. Survey lines were measured with a suspended chain, the tension regulated with a delicate spring. Two chainmen who would chain a mile forward and then back the next day, with a variation of more than half an inch, were considered poor. Transit and level work was equally accurate and records of the small errors found in the marble monuments marking the street lines, set by Randall about 1814, as well as private marks made by the surveyors themselves, were as secret and considered as valuable as the recipe for making Worcestershire sauce. It was a splendid training for a young engineer and when I quit city surveying for railroad engineering my maps were so much better looking than the others that my superiors insisted on making me draftsman of the party, to the exclusion of field work. This was not what I wanted, so it ended in my working all day in the field and often nearly all night in the office. It paid, however, as it gave both experiences in full measure in half the time.

The first important engineering the city attempted was the Harlem River bridges. The authorities wisely looked on those bridges as requiring the same quality of engineering as they would use of architecture for buildings of similar importance, so they were entrusted to the best bridge engineers obtainable, giving them the same power and percentage of costs that architects received. These men were called consulting engineers. The designs of the bridges were made in their own offices and they with their assistants supervised the work. City field parties gave lines and grades and prepared estimates under the consulting engineers. Messrs. Boller, Clarke and Burr were the consulting engineers who built practically all the city bridges before the system was changed to bridge commissions and to the Department of Bridges, now that of Plant and Structures. This department today preserves the methods and traditions of the consulting engineers, handed down through the present chief engineer and many of his staff, whose early training was on the consulting engineers' bridges. They themselves had their early training under the great pioneer American bridge builders, which accounts for many of the splendid bridges about New York.

In my opinion, the plan of employing engineers of skill in a particular branch, with their own specially trained organizations, for projects of that particular kind should have been continued. Only by employment for specific things can individual ability of high order in any profession be availed of, and in no profession is the inspiration and judgment such men possess more necessary to obtain the best results than in engineering. They say that doctors can bury their mistakes and lawyers blame theirs on courts and juries, but the engineer's work is there to plague him and the people who pay for his mistakes in more ways than one. His opportunities for waste are so great in proportion to his compensation that the latter should always be sufficient to obtain the best talent to direct a particular job. As engineers of that rank have many clients, only the time necessary should be asked of them, because such men do their best work through their organizations and their best thoughts often come to them when their minds are supposed to be on something else. I have never seen a job yet in which ten minutes' good thinking at the beginning would not have resulted in important benefits.

When I entered the American Society of Civil Engineers the leading, most popular and most active members were a number of competing bridge manufacturers whose success depended on the quality of their engineering, and most of them became presidents of the society. That is many years ago. Today they would probably be called contractors, very correctly, by many who would not have in mind that the engineering of contracting engineers is as good as that of any one else, and that in addition they are skilled in the art of construction.

WILLIAM BARCLAY PARSONS



The engineer of the first New York subways, a consulting engineer of international prominence, a Colonel of Engineers in the World War

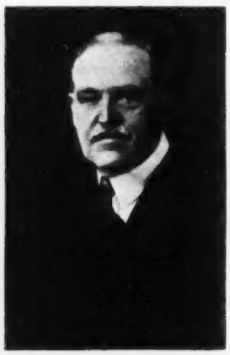
DURING the life of *Engineering News-Record* the practice of engineering has undergone many changes. My own connection dates from 1886 when I returned to New York to begin work on my own account. Since then the field has not only broadened but has become intensified with an amount of special knowledge in each branch that was not dreamed of forty years ago. The interesting feature of this is that we do not find today as might have been expected many specialized experts as consulting engineers. In fact, the tendency seems to be the other way, and instead of individuals practicing on single lines as men like Theodore Cooper and George Morison did, we have firms, or more particularly, large engineering concerns composed of groups of specialists prepared to handle engineering work on any basis from a preliminary study to complete financing and construction.

This result is not so surprising as it might appear to be. Engineering is a complex subject and every advance in a single specialty is reflected in the whole. What accomplishment needs, is not so much a single man but a group of men each contributing his special knowledge. In one sense this same movement is tending to eliminate the consulting engineer or the engineer in private practice. In my own experience I have seen fields of engineering calling for consulting work come into being and pass away.

So great a part does engineering work play in modern industry that great commercial concerns whose very existence and size could not be foreseen forty years ago are today so large as to justify their having a complete engineering staff of their own headed by able men receiving

proper compensation. This growth has particularly removed railroad work from private practice. Railroad companies today do all their own work with their own staffs. Even banking houses who a few years ago were good clients for consulting engineers, today have their permanent organizations and frequently on a large scale. It is interesting to note that even states and municipalities are following in the same line. There was a time when the state or city commissions employed outside specialists for advice. Today the work that they perform is so great as to justify their retaining such men on permanent salaries.

S. M. FELTON



The president of the Chicago Great Western R. R., Director General of Military Railways during the World War

MUCH CAN be written about the difference between engineering of today and when I graduated at the Massachusetts Institute of Technology in 1873.

At that time we had courses in civil, mechanical and mining engineering, a course in chemistry and a physical laboratory. Today we have engineers who specialize in work of every kind, and the demand for their services is such that the technical schools are hardly able to meet them. We have the sanitary, chemical, industrial, highway, drainage, hydraulic, mining, naval, structural, radio, automobile and electrical engineers.

Much of the rapid progress in the development of our own country is due to the advancement in the science of engineering. Chemical engineering played an important part in the recent World War.

The mechanical engineer is responsible for many changes and improvements in railroad equipment, such as the air brake, automatic coupler, superheating, feedwater heaters and other improvements without number. Locomotives have increased in size and weight from the 50-ton engine to the monster Mallet, weighing over 400 tons. Freight cars, from the 10-ton wooden cars with link-and-pin coupler to the 110-ton all steel, selfclearing cars, equipped with automatic couplers and air brake. Passenger cars, from the lightly constructed, poorly lighted wooden coaches to the palatial parlor and Pullman cars of all-steel construction of today.

Naval engineering has advanced in a similar manner; so has electrical engineering. It would seem as though we have almost reached the limit of progress in engineering, but undoubtedly another half century will bring advances and improvements which today are unthought of.

S. WHINERY

The dean of the road building engineers. A member of the American Society of Civil Engineers since April 1, 1874

WITH an ordinary common-school education, including a slight knowledge of elementary algebra, I began, in the early part of 1867, my studies and experience in engineering, at the rear end of a chain, on the location of a railroad about 75 miles long, in Indiana. I mention this as probably typical of the mode of entrance of young men into engineering at that period. I was later connected with the construction work and came to know the make-up of the engineering organization. As I now recall, there were two young men who had recently graduated from engineering schools. None of the others in the engineering force, from the chief engineer down, had ever been inside an engineering or technical school. It is probable (though I have no definite information in the matter) that substantially like conditions existed on the other railroads and public works of the time, and that the great majority of the engineers of that day who had attained eminence in their field of work were without any special educational preparation for it. They were emphatically selfmade men, when the making involved not only self-education in technical fields, with perplexing problems, but hard work and persisting energy. Satisfactory engineering text-books were scarce, and the periodical engineering literature that has become such an important factor in the progress of the profession, was wholly absent.

In this respect engineering has undergone a veritable revolution. Not many young men now enter it from the real ground level. The engineering and technical schools and their output of graduates have greatly increased. The young engineer now starts off with a well disciplined mind, and a fairly complete kit of intellectual tools, scientific, mathematical and mechanical. And he finds the opportunities for the application of his constructive skill and creative genius vastly greater than they were half a century ago. More and better and bolder work may reasonably be expected of him; and in this respect he has not disappointed us.

In those earlier days engineering was seldom spoken of, in this country at least, as a *profession*, and while that term is commonly applied to it today, it is not yet, and will not become a real profession until engineers comply with and enforce the principles and practices that the word implies. True professional service consists in the disinterested application of special knowledge and skill to the use and for the benefit of others, wholly free from the element or motive of prospective commercial or business gain. When actuated by motives of personal profit it becomes, in fact, nothing more than a skilled craft or trade. Until this basic difference is recognized, emphasized and enforced, and legitimate practitioners differentiated by proper registration it will continue to be a misnomer to speak of engineering as a profession. Toward this important goal but little satisfactory progress has been made in the last half-century.

DESMOND FITZ GERALD

Past - president and honorary member of the American Society of Civil Engineers. Long a leader in water-supply engineering

THE ESSENTIAL difference that I remark between engineering of today and engineering when I started to practice in 1866, is that while the same general and fundamental principles are involved, the details of practice are in most respects quite different. Engineering designs are on a materially larger scale and the resources at the command of engineers are more varied and more powerful than in the earlier days.

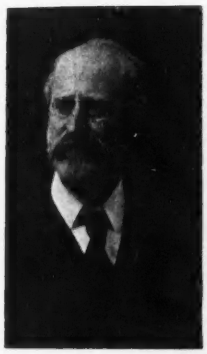
When students first begin their practical work they usually have to be contented with filling positions at the bottom of the engineering ladder. This often means surveying or the staking out of work designed by older men. As far as this early work is concerned perhaps there is not so very much difference between the older and the newer practice, although in some cases there are wide differences even at the foot of the ladder. For instance, when the Hoosac Tunnel was built, in the western part of Massachusetts, an excellent opportunity was afforded for the development of new ideas, both in design, the execution of the work and its supervision. If this tunnel were built today, it is extremely doubtful

whether it could be executed in a better manner than in the earlier time.

In some branches of the profession, however, great strides have been made in these later days and bridgebuilding is one of them. Long and important suspension bridges were constructed many years ago, but present day practice has learned much from the failures of the past. The intelligent use of the metals has progressed in later days.

If we compare the modern railway with those of the Civil War, we find great strides formed in almost all branches, heavier engines, longer trains, electrical engines and many devices in which electricity plays an important part. This is certainly a modern tool which has opened a wide door to the efforts of modern engineering. The manufacture of huge turbines and the application of the necessary power to drive them has made wonderful progress, but in this connection we must not forget that in the earlier years, the genius of Francis produced the high duty turbine and faultless methods for gaging its efficiency.

CLEMENS HERSCHEL



Eminent hydraulic engineer, inventor of the Venturi meter, past - president American Society of Civil Engineers and a member for fifty-five years

IN 1864 the line of cleavage between the civil engineer and the surveyor had with us hardly begun to develop. Civil engineers generally called themselves "engineer and surveyor"; or else "civil engineer and surveyor." It was a favorite figure of speech with the writer, who by study abroad felt that he had advanced to the position of a civil engineer, to say that there was as much difference between a civil engineer and a surveyor as there was between a physician and an apothecary; professions which likewise at the time were sadly confounded in the public estimation. Nor need this blending of the engineer and surveyor in public appreciation of the time now surprise any one.

The first man who in English speaking countries signed himself a civil engineer, thus breaking away from the appellations of hydraulic architect, or military engineer, was John Smeaton, about 1780; the builder of the long enduring, now dismantled Eddystone lighthouse.

From 1780 in England to 1810 in the United States is not a great leap in the civilized arts; and again from 1810 to 1864, or even from 1780 to 1864, is a moderate span in the world's development. So that, as before said, it need not surprise us that in 1810 there were but few who were confessedly members of the profession of civil engineers in the United States, nor many even in 1864. Such as we had originally were mainly the outcome of navigation canal or railroad, and a small group of domestic water supply works, construction; drawn from military engineers, who had graduated at West Point; from engineers imported from abroad; and from native stock, who, graduating from the practice of land surveying, and by exercise of "horse-sense" and "main strength" claimed to be and in reality became civil engineers.

In the winter before the close of the Civil War, the writer designed a bridge to be built on a railroad then projected in the Queechee country of Vermont (about the first independent work he ever did as a civil engineer) and well remembers that the chief engineer of that railroad had become such by virtue of a domicile in the vicinage, and because he had been the author of the popular treatise of the day on "Mental Arithmetic."

Both the original water supply works of Boston and of New York, of the Cochituate, and Croton, had gathered what became the nucleus of the growing number of hydraulic engineers of the country, in the early forties of the last century; and in Boston this became the cause for the chartering, by act of the Great and General Court of the Commonwealth, of the Boston Society of Civil Engineers; thus the first organized society of civil engineers in the United States.

All this, again, casts a side light on the standing of the profession in the early years of its existence in the United States. Every engineer knows what that standing has become, and is presumably doing his best to exalt it. The essential difference between engineering of today and engineering of sixty years ago is evidently that produced by sixty years of the growth of the country, and by the host of inventions that these sixty years have seen brought to fruition. In 1864 we did not have 115 million inhabitants; nor 48 states of the Union. California was practically farther off from the Atlantic seaboard than Tasmania is today. This conquering of distance has been largely the work of the civil and mechanical engineer.

The writer's principal work in his experience has been in water power; and confining himself to that branch in the present discussion, he can point out some marked contrasts between then and now.

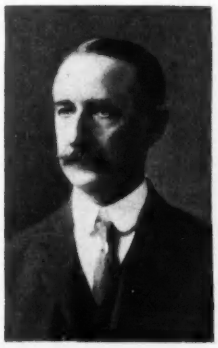
Some time in the seventies James B. Francis proposed cutting up the several hundred feet of fall in the St. Louis River into 20-ft. steps, or terraces, with a railroad (which was actually built, and then abandoned) to serve the mill sites thus formed. Today, the power company that controls this river is very glad to use the whole fall of the river on its turbines and would use more if it had it.

Now this is the result of the invention of the electrical transmission of power; an invention that future historians may perhaps write down as having effected more social changes among the inhabitants of the earth than any one other that can be segregated.

Another example of these, its effects. When the writer was in charge, 1879 to 1889, of the water power at Holyoke, Mass., he was well acquainted, of course, with the attributes of the sources of water supply to the Holyoke power. Among them was the Deerfield River, and as goes his best recollection and estimate, if anybody had proposed to invest $200,000 in a power plant on the Deerfield River during the period named he would have been considered of the class taken cognizance of in the saying that "a fool and his money are soon parted." Yet today the New England Power Co. has invested over twelve millions of dollars in power plant properties in that same valley and is sending power to Worcester and Providence, and its securities are sought after by the prudent and the thrifty.

These changes have come within the last thirty-five years—no need to go back to sixty years ago.

GEORGE F. SWAIN



Past President, American Society of Civil Engineers. Professor of Engineering at Harvard University

IN ANSWER to the question, "What is the essential difference you remark between engineering of today and engineering when you started to practice," I will reply that, referring to conditions in this country, to my mind the most striking difference is the increased attention now given to abstract theory and to testing and research, both in college training and subsequent practice.

When I began to practice, engineering in this country was largely practical and in the hands of men who had little theoretical training. They were, however, men of sound judgment and common sense and they achieved great results. Comparatively few practicing engineers were graduates of engineering schools. In the engineering schools, indeed, the more elaborate mathematical theories were not taught, and probably not known, and it was necessary for a young man to go to Europe to study in order to learn them. This I was obliged to do myself, in order to become familiar with the latest developments in the strength of materials, structures, and hydraulics. On the continent of Europe, and especially in Germany, on the other hand, theory was highly developed and taught in the schools.

When I was going to school, aside from books on surveying and railroad curves, the only text books used were Rankine's "Civil Engineering" and his "Applied Mechanics."

Since that time, engineering in this country has become largely Germanized, partly through the influx of a good many young men trained abroad and partly through the great development of the abstract mathematical and theoretical branches in our schools. When I began, the "Transactions" of the American Society of Civil Engineers consisted almost wholly of practical discussions. Now they are full of theoretical discussions with complicated formulas as long as your arm. In the practical work of designing too, these complicated theories are used where, formerly, empirical rules or the judgment of the engineer were relied upon.

Along with this has come a tremendous development in mechanical testing. When I began practice, there were no testing laboratories in our schools and practically none elsewhere. Now, every conceivable subject and almost every conceivable case is being tested, and "researches" by the score are being carried on in practically every field of engineering.

While nobody realizes better than I the importance of abstract theory, yet I cannot feel that this change has been altogether for the good; nor do I believe that we do any better engineering work than we did in the old days, broadly speaking. There is no question in my mind that too much theory is worse than too little. Furthermore, all theories are based on assumed conditions which are never the precise conditions of practice, and are frequently very far from them. Yet the abstract turn of mind, which has been so largely developed, tends to cause a reliance upon the results of such theories because they are worked out by a long process of mathematics, and the initial assumptions are forgotten while the mathematical work is being done. The case is somewhat similar in testing, which is now resorted to frequently as a substitute for thinking, although, of course, everyone must admit that it is only by testing that the fundamental facts regarding materials can be ascertained, and that tremendous and valuable advances in our knowledge have been brought about by testing, and could have been successfully accomplished in no other way.

I think, on the whole, there is less initiative now than there was, and that this is particularly the case among college-trained engineers who have had this intensive theoretical training. Such training, instead of cultivating self-reliance and initiative, is very apt to cultivate a reliance upon books and formulas. A young engineer now having a problem before him is very apt to rush to the library and return with an armful of books in which he will seek to find the solution. If he had no books, he would have to work out the solution himself, and if it is a theoretical question, the chances are perhaps ten to one that he will now find a formula in the book and then will misapply the formula to the case in question.

GEORGE H. PEGRAM

Past - president Am. Soc. C. E. Chief engineer of Interborough Rapid Transit Co., of New York City

THE PAST fifty years have seen the substitution of steel for iron in railroad and bridge work, and an equally long step in the substitution of open hearth for bessemer steel; now progress is shown in the use of alloy steels in bridges of large spans. Structural design has naturally followed the improvements in materials.

The developments in electricity, the application of the gas engine, the improvements in steel and the practical substitution of mechanical for muscular energy—all the products of engineering have transformed the world.

This progress has imposed specialization upon the profession of engineering. On the other hand, the co-ordination of these specialties in large undertakings has called the engineer to administrative positions as the heads of industries, railway systems and organizations which combine financing, administration and construction with engineering.

Thus a broadening process has been forced upon the engineer and with it greater influence and participation in the comprehensive and systematic development of the country which is sorely needed.

To get the best results, we must give more consideration to the early training of the engineer.

Intimate association with strong personalities is the best school for the formation of business habits and character.

I recall with grateful remembrance the close association with the following men, long since dead, each of whom I regard as the greatest man I have ever met in his line of work: Dr. C. M. Woodward, of Washington University, St. Louis; Colonel C. Shaler Smith, the noted bridge engineer, whose life should be written as an inspiration to youth; William Sellers, the great maker of machine tools; General G. M. Dodge, the greatest railroad builder of any time; and S. H. H. Clarke, successively president of the Missouri Pacific and Union Pacific systems, who emphasized the human element in the management of men.

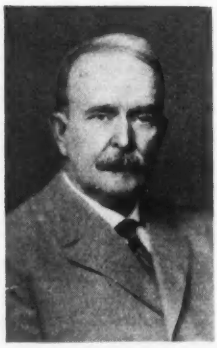
Such intimate associations cannot now be enjoyed, any more than the apprentice in a trade now works with his master, as in former times. The change that has come over the world on account of the "bigness" of things has swept such opportunities away. Compensation, it would seem, can only be supplied in a measure by methods of education, just as the vocational school aims to replace the old apprentice system. It, therefore, becomes important that the profession of teacher shall be made more attractive so that men of strong personality will be secured for such work.

I feel that our engineering education might be reformed in other ways. With the rapid increase of the knowledge of the world, more and more work has been required of the student and a large part of his time has been taken teaching him facts which could as well or possibly better be learned later in life. Principles can be acquired only at school and stress should therefore be put upon their teaching.

The originality and initiative of the student should not be smothered by too exclusively prescribed work. He should be given a greater choice in his studies and more discretion as to how they shall be pursued. Let it be more "up to him."

The regular course of study should be finished at twenty-one years of age, whether the studen graduates or not. Too great importance is attached to degrees. This will leave part of the formative period of life for co-ordination with the workers of the world.

W. O. WINSTON

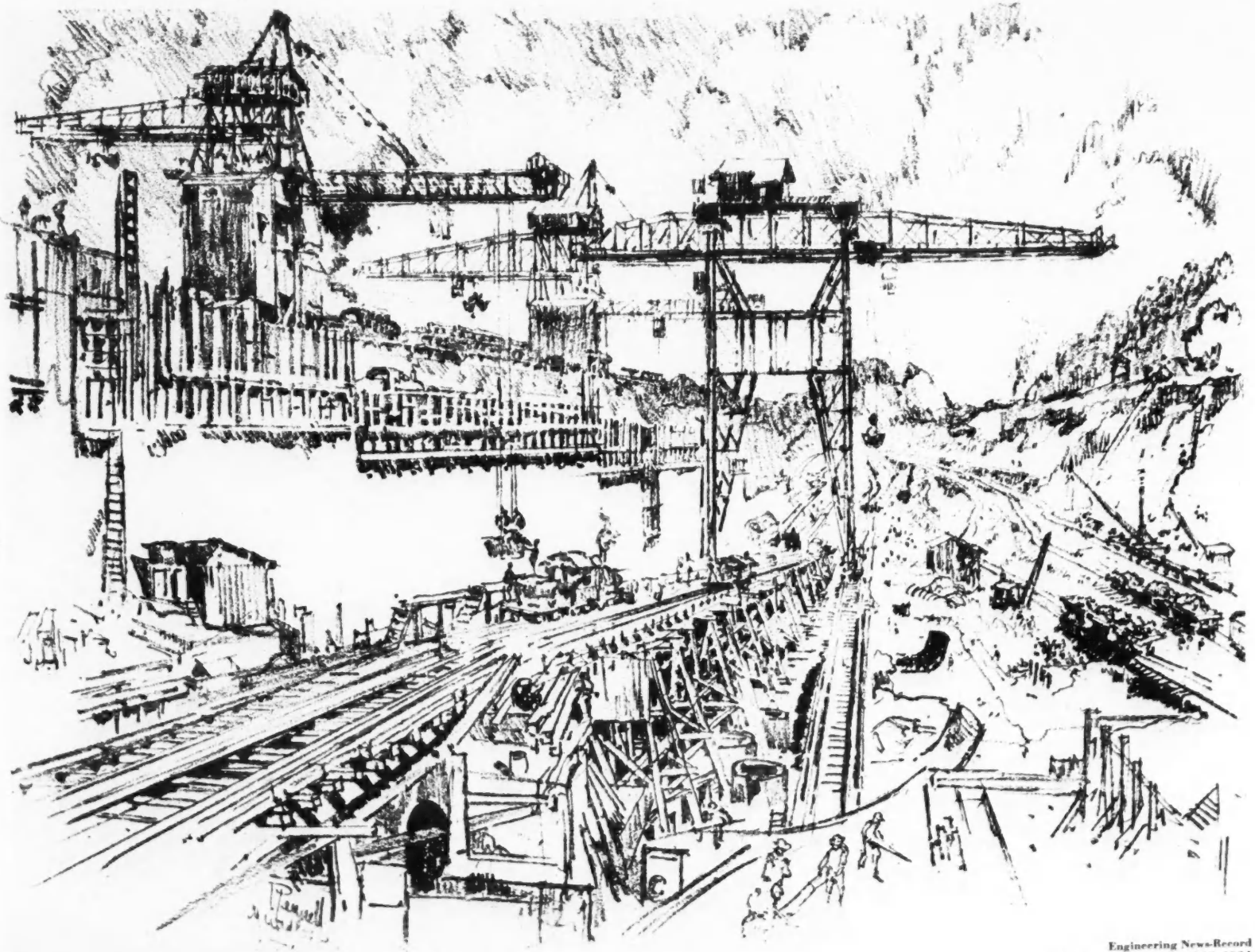


Dean of American contractors Railroad builder since the post civil-war period

WINSTON BROS. entered the construction game in 1875. Their first railroad construction contract was executed in the fall of 1878. What I shall say on "Then and Now" will have reference to railroad construction, and particularly to the grading equation of such construction.

There has been no change in the railroad grading problem since 1878. Then it was, as it is now, one of cuts and fills, of pulling down and filling in. There have been great changes and improvements, however, in the appliances for attacking this problem. Prior to 1878, excavation, after being loosened, when necessary, by explosives, or picks and bars, was loaded, speaking generally, by hand into wagons, carts and wheelbarrows, to be transported to the fills. To a very large extent machinery now does the work both of excavating and transporting.

The first steam shovel was designed and patented by William S. Otis, of Massachusetts, in 1837. A machine was built in Philadelphia for Fairbanks, Car-



Miraflores Lock at Panama Under Construction—By Joseph Pennell

Engineering News-Record
Fiftieth Anniversary, April 17, 1924

michael & Otis, and used by them that year on a railroad construction contract had by them with the Baltimore & Ohio Railroad Co. for work in Maryland, but it was not until after 1882 that steam shovels came into common use.

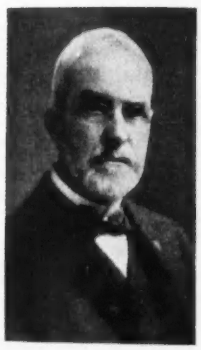
The first rocker type cars came into service in 1870. They were patented, built and introduced by Francis Peteler, of Minneapolis, Minn., and were of one-yard capacity.

The dipper capacity of the first shovel, referred to above, was three-quarters of a yard. Shovels built as late as 1882 had dipper capacities of not exceeding a yard and a half. Now shovels have dipper capacities up to eight yards or more, and cars have capacities up to thirty yards or more.

In 1882 cars when loaded were drawn by horses or mules, over a track of 20-lb. rails. Now they are drawn by locomotives of various weights, over tracks having rails of weight to 75 lb. and over.

While the capacity output of machinery, both for excavating and transporting, has increased a number of fold since 1882, the unit cost of work is now probably more, rather than less, than it was then; this in good part because of the increase in labor wage, coupled with a decrease in labor efficiency and stability. However, in many instances we can do now in three months what it would have taken us twelve months to do then.

JOHN C. TRAUTWINE, JR.



Author and social philosopher. Second in the Trautwine line. A consulting engineer in Philadelphia

CAN THERE be question as to what distinguishes engineering today from engineering of a half-century ago?

Compare the text and advertisements in this issue of *Engineering News-Record* with those of Frost's *Engineer-Surveyor* of 1874.

The outstanding difference is one of *bigness;* bigness of development in itself; bigness in the dimensions of the organizations which now do our engineering; incomparably bigger bigness in its promise for the human race.

Prior to the advent of the steam engine, the total advance of humanity, from the pure individualism of savagery toward civilization, might be represented by the ordinates to a nearly horizontal tangent, not far above the axis of abscissas.

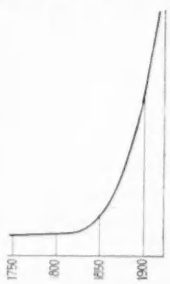
But the appearance of the steam engine, about 1800, marked the point of curve, for it meant the beginning of big business.

The steam engine, and the machinery driven by it, demanded and created combination of capital for their ownership and maintenance; combination of labor, for their operation; and a loose combination of buyers, to take away the product and to furnish the profits. From that point the curve has descended ever more rapidly, its tangents forming ever steeper angles with the base.

Soon came the steamboat and the railroad; and, with them, the beginning of the end of individualism in business.

Today the world is driving headlong toward gigantic consolidations of already gigantic railroad and power systems, and toward action, by the community as a whole, to protect its forests, its streams, its fuel supplies, its very life, against the depredations of the perfectly legitimate and perfectly anti-social profit-seeker.

The profit system gave our forebears *things* (plows, spinning-wheels, horses), by means of which they obtained that *service* which alone they needed, and for the procurement of which the *things* were indispensable. Hence, from the beginning, history has been a tale of struggle for the private possession of things—a tale of strifes, of frauds, of cruelties, of poverty, of wars.



But the modern system (rendered possible and inevitable by engineering) gives us, freely and abundantly, not *things,* of which we may be robbed, but *service* (fire and health protection, power, irrigation, flood-control, city planning), which no man can take from us.

Hence, as the modern system displaces the ancient, we are being relieved of the necessity of scrambling with our fellows for pennies, and are being unconsciously transformed into ladies and gentlemen. Christianity is at last being made practicable, and Dr. Kammerer may well predict a race of supermen.

No amount of preaching or of conscious reform effort could have brought this about. It is the outcome solely of modern *inter-system* competition, in which, as in inter-individual competition, the appeal is to the selfishness of the customer, and survival is to the fittest. Today we have toll-free roads, not because idealists have agitated for socialism, but because the motorist finds that socialized roads better serve his selfish purpose. It is the irresistible push of universal selfish demand which assures to us the early triumph of the modern system.

But let not the engineer preen himself as an altruist. While the ancient system persists, greed remains the world's driving force. Like his fellow-man, the engineer has been working primarily for his own emolument. Presumably the coral insect is indifferent to the fact that it is building coral reefs; and the average engineer is not concerned to know that his profession is working the salvation of the world.

JOHN W. HILL

One of the first engineers to fight typhoid fever. Chief engineer for original water filter plant at Philadelphia

MY LOT has been largely cast in the lines of steam and water power, water-works, property valuations and kindred work. I came thus to know some of the most eminent members of the profession, James B. Francis, Chas. E. Emery, Edwin Reynolds, Moses Lane, C. Shaler Smith, Alexander Holly and a host of able and brilliant men a half century ago.

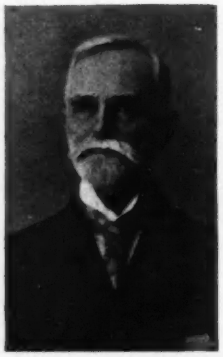
In the early days (1874) the engineer designed practically all of the many details required for his work, which now can be listed from the multitude of the trade catalogues. The engineer was supposed to have some special training and knowledge which was necessary to the work in hand. Now all or much of this is supplied to the client by the great corporations and an ordinary traveling salesman. Fancy, Moses Lane, or W. E. Worthen, trying to work out today a water-works proposition with a bunch of modern salesmen at his elbow. Either of them might be convinced that the experience and training which is exemplified in the Milwaukee and Brooklyn water-works 50 years ago, was very commonplace and hardly worth while today. Some things progress forwards, and some things progress backwards.

The romance that prevailed in engineering fifty years ago has latterly altogether vanished. In the early days, generally, one's compensation was agreed upon and assured, and ever after his whole soul and resources were absorbed in his work. The results are the milestones along the pathway of time.

Experience seemed to count most in obtaining worth while commissions. Actual cost of engineering services was of less concern to your patrons than the assurance of competent service and safety to your work. Competitive bidding where the lowest price won the job was unknown and an invitation to engineers to submit propositions and outline plans when there was no intention to employ them, would have been viewed as a breach of business morals.

Fifty years ago sanitary water analysis was performed very much as Wm. Ripley Nichols described it ten years later. Culture experiments in gelatin and subsequent examination of colonies by the aid of the microscope, as proposed by Dr. Koch, came along later. Thirty years ago there were many able skeptics of the water carriage of the typhoid germ.

ONWARD BATES



An engineering consultant of exceptional distinction. Past-president and honorary member of Am. Soc. C. E.

THE ENGINEER who was of working age in 1874 and whose eye is not dim nor his natural force abated in this year of our Lord 1924 may look backward over the most eventful and interesting half-century of the world's history.

Fifty years ago he was handicapped in the acquirement of the technical education necessary in his practice, by the dearth of engineering schools, books, periodicals, precedents and examples, as well as the lack of opportunity for association with others capable of imparting to him needed instruction. His practice was isolated, many of his problems were new to him and for want of education he was required to act on his own initiative, with courage to accept responsibility, patience to await results, and with perseverance in correcting his mistakes. In the tedious school of experience he gained in self reliance and strength of character as well as in theoretical knowledge.

We are boastful of the progress of engineering in this last fifty years, with good reason for our pride, but a word of caution is not out of place at this time.

Take notice of what has happened in the last fifty years and compare the conditions of today with those recited for 1874. We have more than we need of printed technical matter, facilities for engineering education in schools, lectures, society transactions, libraries for the study of any subject, and of specialists to instruct us in any branch of the profession. This age is prolific in inventions, scientists are constantly employed in experiment and research, and engineers individually and in societies are engaged in co-operative work. And what is more important, we have confidence in ourselves and the public has confidence in us, which opens the way for engineering achievement. There are no trade secrets in the works of engineers and each engineer is a teacher of others. It used to be said that "Engineers are good in spending the money of others," but that derisive statement is now refuted by the readiness of capital to provide funds for the most costly works and in such liberal measure as hardly to be understood by old engineers trained in the most economical use of small sums. How wonderful is all this! The question arises, will the engineers meet the demands of the future? Let us hope so and work to that consummation.

The profession of engineers is not overcrowded, nor are there too many students looking forward to its practise. Among our engineering graduates there are many who were not fundamentally intended to be engineers, but what of this, they may enter other vocations with the assurance that their education will not be wasted, and if proof of this statement is desired, they need only study the lists of graduates not engaged in strictly engineering occupations, to learn that with such as are unsuccessful the reason lies not so much in their education as in other causes quite apart from it.

JOHN ERICSON

In the engineering service of the City of Chicago since 1884; for many years, and now, its City Engineer

THE problem of bridge design and construction, particularly movable bridges, has undergone a decided change in the past forty years. In my early days loads were light and slow moving. Traffic was not dense and time of operation of less importance. The site was more or less free during time of construction. Today conditions are different, and the problems, especially in a large city, very much more intricate. The light, horse-drawn vehicle and cars have given way to heavy motor cars, trucks and electric railway equipment. The speed of travel has increased many fold, introducing serious dynamic problems, which formerly could be ignored. Tunnels for various purposes and other obstructions interfere with foundation work. The dense street and other traffic makes the slightest interruption serious. For these reasons the design must provide for rapid operation by means of modern electrically-operated machinery, and the construction must be carried on with the least possible interruption. Elaborate safety devices are required, and yet, in the days of my early experience, the light, hand-operated bridges served their purpose more satisfactorily than do the complicated structures of today.

In the early eighties the best of our pumping machinery for municipal water supplies consisted of simple beam engines. Two such were at that time installed in a Chicago pumping station. They were of 15-m.g.d. capacity each. The steam pressure was 60 lb. and the head pumped against 150 ft. The duty obtained was 90 million foot-pounds per 100 lb. of Pennsylvania anthracite coal, and was at that time considered exceptionally good. Since that time the developments in the compound, triple expansion, and even quadruple expansion, engines have been more or less rapid. In later years these are being supplanted by steam turbine or motor-driven centrifugal pumps of 75-m.g.d. capacity each, with 150-ft. head, 300 lb. steam pressure, and 200 deg. superheat, carrying with them guaranteed duties of from 200 to 212 million foot-pounds per 1,000 lb. of steam.

The advance in boiler designs since those days when externally fired tubular boilers were the prevailing practice has also been more or less marked. The internally fired tubular, and later the modern water tube boiler, with pressures up to 300 lb. or more, are becoming the general practice in water-works plants.

The use of liquid chlorine and the present scientific treatment and filtering of water and purification of sewage, with a corresponding great reduction in water-borne diseases, were unknown in my youth.

FREDERICK A. McCLURE

A pioneer municipal engineer for forty-three years, and twenty-three years the City Engineer of Worcester, Mass.

LOOKING back over a period of more than fifty years' practice, the essential differences between engineering of today and engineering when I started to practice are to my mind very great. Differences in the problems to be dealt with, in the materials used, the manner of execution and the application and use of machinery, have brought about a vast change in the practice of the two periods of time.

In those days the engineer was like an old-fashioned family physician, he did everything; specializing was uncommon.

In New England particularly, sanitation and many other branches of engineering had received little or no consideration. The men of large practice who were looked to as leading in the profession were for the most part engaged in the building and operation of railroads, but they also worked on such problems as water supply, sewerage and many other questions of municipal policy.

Portland cement was largely foreign and expensive. Concrete, the material that has so revolutionized our building methods, had not made its appearance. Sewers were made largely with Rosendale cement mortar and brick sewers were laid with the same material.

With the growth of technical schools and colleges, practices and methods have become more standardized. Literature on almost every subject has become common and engineering publications have co-ordinated practice everywhere.

ALBERT LUCIUS

Veteran designer of large railway bridges and steadfast upholder of high standards of design

LOOKING back over a period of fifty years in the special field of railroad bridge construction, it appears as a steady growth in magnitude, capacity and adjustment of structure, anticipating the requirements of service both in weight and speed of trains. No essentially new principles have been evolved and introduced in design and detail, but the stresses to which members are exposed under the actions of moving masses are more thoroughly understood and the appreciation of their effect is more definitely expressed in their detail.

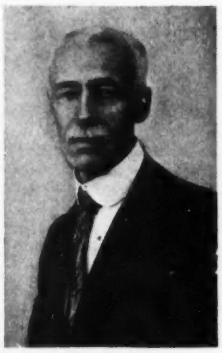
Improved metallurgical processes have provided more suitable materials of construction in great variety of size and shape. Tools, shop facilities and fabrication processes have greatly increased in scope, efficiency and precision, and methods of erection have become prominent features and part of the design. The engineer at the present time is limited by little else than the ultimate strength of the material in providing structures of such magnitude and capacity as are now called for. The philosophy of engineering in general is a harmonious co-operation of many men and many minds for the purpose of physical existence and development.

The older bridges were largely trestle constructions, built with little consideration for other requirements than the support of vertical loads and wind forces, and the available building materials were timber and iron rods. Greater openings were spanned by trussed beams and these developed into short paneled trusses carrying the tracks on more or less unconnected floor constructions. Wood gradually was displaced by iron and steel. The shape and style of trusses and connections followed at first the original models but soon branched out and divided sharply into two principal types, the lattice truss and the pin-connected truss.

The directness of the stressing of members, the simplicity of construction, fabrication and erection, the ability to deliver at the bridge site all members entirely fitted and finished and to complete the erection by the mere driving of pins, which at the same time established the correct position of the members and maintained the profile of the truss, were advantages and expansion of size and capacity and improvement in detail followed.

The inherent defect of pin connections, however, is the concentration of load at the pins and its transfer on mere lines of contact with consequent deformation on these lines which gradually impairs the correct adjustment of members. The rigidity of the riveted truss and the advantages of plated joints and connections which distribute the load over large surfaces and provide numerous points of exchange through rivets are more generally recognized, and proper fabrication methods will speed their introduction and result in more rigid structures. The drift of construction for the mass of short-span bridges will probably be in favor of the arch type of truss and concrete and steel as the building material.

HORACE ANDREWS



For many years City Engineer of Albany, N. Y. An early contributor to the technical press

RECOGNITION by the public of the relative importance of the engineer, as contrasted with the indifference of forty or fifty years ago, can not fail to be observed. The attitude of greater deference, of a higher degree of respect, seems to have grown more noticeable in the years of the twentieth century.

The attainment of this advanced stand in public estimation is due primarily to the great increase in means whereby the engineer may obtain his training and add to his store of skill and information.

The high plane of excellence of engineering schools gives adequate reason for expecting a young engineer to start his life work as well equipped as he would have been after several years of practical experience in those bygone days which the older engineers look to in retrospect.

Perhaps the greatest difference between a profession and a trade is that the professional man is eager to give a full and complete account of his methods as well as of his results, he has no "trade secrets." The accumulation of the experience of many, especially the record of failures, furnish a storehouse that can be worked with assurance of rich reward, thereby disaster may be avoided and success achieved.

The present-day engineer would feel badly handicapped if he were asked to carry out his plans without the use of electricity, gasoline, and internal combustion engines. Half a century ago there was little Portland cement; reinforced concrete scarcely existed and was still in the experimental stage, structural steel was just coming into use, asphalt for paving purposes was hardly known and the use of oiled pavements quite unheard of.

The old-time engineer had, perhaps, less competition; at all events he could at starting obtain positions on railroad work almost everywhere. On the other hand the engineer had, for many years, to convince an indifferent public that the education of a professional school was essential and that the habits of thought obtained at such a school were a most valuable asset and one that added much to his usefulness.

MANSFIELD MERRIMAN

Pioneer engineering educator and author. Professor emeritus of Lehigh University

AS AN occasional contributor to the columns of the distinguished succession which is now *Engineering News-Record* I have from the first been a subscriber and am proud to be the possessor of a copy of every issue from Volume I of 1874 to Volume XCII of 1924. My first contribution was in July, 1876, "On the New Science of Graphical Statics"—a subject which has long since been developed into one of the most useful tools which every engineer should keep sharpened on his workbench.

The appearance of the first ancestor of *Engineering News-Record* was practically contemporaneous with the beginning of the study of what we have come to know as modern engineering education. Both of these movements have grown and developed, until today, as we look back at those early beginnings, they seem crude and elementary. Both of them were conceived and founded in a spirit of endeavor and of hope. They were carried on through the sustaining influence of a faith which, as later developments have shown, has not in all respects come to be realized. In retrospect it seems as though our development has been so rapid that we no longer cherish the things which are of fundamental value. The present generation craves excitement and artificial amusement. It has lost both the ability to entertain and to think for itself. Individual poise has given way to the unintelligent thought of the crowd. While the sum total of our knowledge is manyfold greater than was that of fifty years ago I fear that the average of happiness and true contentment has decreased in nearly direct ratio.

For the greater part of these fifty years I have been active in the field of engineering education and while many

theories have come and gone there has been little of basic development. In the fundamentals there has been no change, nor indeed is change possible. The effort must always be to train men to observe and, having observed, to reason logically. No system which fails to instil the student with love for his work, with devotion for the truth and with ambition for human development and personal achievement, can endure.

J. C. BLAND

For thirty years engineer of bridges of the Pennsylvania Lines west of Pittsburgh. A pioneer in the design of heavy railroad bridges

THE TRAITS which to my mind characterized the engineer at the time when *Engineering News-Record* was in its early manhood, were individuality, originality, resourcefulness, independence, and breadth of view; and naturally these traits were reflected in the practice of that day. Standardizing practice, though in the air, had not as yet become actual, but it had not long to wait. The marked development of the railroads during the last decade of the past century and the first decade of this gave rise to the desire for greater uniformity in engineering practice, which culminated in standard specifications.

Engineering has but followed the trend of the day, as seen in the social and political worlds. Committee work replaced the individual work of former days, and practice became standardized with all of its benefits and as well its disadvantages. Specializing in the various sub-divisions of engineering became the vogue, especially accompanying the great developments in electricity, and, as in medicine, we soon had specialists to cover not only the three main divisions of engineering—civil, mechanical and mining—but also the newer fields, electrical, marine, etc.

Under these new conditions, of standardized practice and the numerous specialized subjects, the type of men changed to fit the situation, and it seemed as though the engineer would at no distant day be replaced by the highly trained technician.

The engineer of the earlier day, while holding fast to his own opinions, was tolerant of those of others; he had breadth of view—"magnificence of mind." Today he must practice after the manner set forth in the standards, to violate which is the unforgiveable sin.

The young engineer, well grounded in the principles of his science and about to begin practice, has the guidance afforded by the rules of practice, made by his elders in committee—men eminent in their respective fields. This is all as it should be, but the danger is that the rules of practice have proven so good that they are too apt to be looked on as final, and to doubt them is rank heresy.

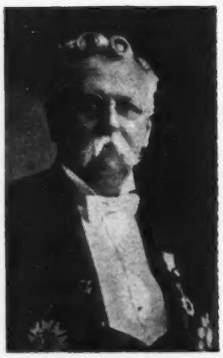
The role of "Athanasius contra mundum" is at best not an enviable one; now it is opposed to the spirit of the times and is not to be tolerated, evidence of which is found in many fields quite outside engineering.

Nevertheless, I think we shall always find men possessing the five main traits of the early engineers and equipped with a thorough knowledge of mathematics and the physical sciences, who are capable of practicing "the art of directing the great sources of power in nature to the use and convenience of man," and the defining marks of such engineers may possibly be those given by a recent writer in the following words:

"They will not be the marks of mere 'efficiency' nor of mere technological knowledge nor of technological skill—they will not be mere engineering technique of any kind, whether 'civil' or 'mechanical'; these things will be important, indispensable, but they will not constitute the Great Engineer. The characteristic marks of the Great Engineer will be four: magnanimity, scientific intelligence, humanity, action."

That there has been unprecedented advance in engineering knowledge during the past thirty-odd years goes without saying. Whether or not that advance has been hampered by the present worship of standards and of specialists remains a very serious question.

J. A. L. WADDELL



For nearly fifty years a leading exponent of the art and science of bridge building at home and abroad

SINCE I began my professional career nearly fifty years ago bridgework has passed from a business or a trade, first into an art, and finally into a science. The main items of development are as follows:

A. The establishment of the so-called exact method of computing static stresses in girders and trusses of railway bridges by using assumed axle loadings and spacings—also of the equivalent-uniform-load method deduced therefrom, and the latest modifications of this labor-saving device.

B. The establishment of standard live-loads for both railway and highway bridges, and the gradual increase in these until they are now fully three times as great as they were at first.

C. The evolution of the formula for impact, by which the dynamic effects of rapidly-moving live-loads are reduced to their static equivalents—an innovation of great importance.

D. The evolution and publishing of standard specifications for the design, manufacture, and construction of both railway and highway bridges.

E. The evolution and development of the cantilever bridge.

F. The gradual development of the theory of stresses in swing-spans and the perfecting of the details of these spans.

G. The evolution and development of the vertical-lift bridge and of various kinds of bascules until these two types have supplanted the swing-bridge.

H. The adaptation of electricity to the operation of movable spans, thus cutting down the cost of operation.

I. The passing from wrought iron to carbon steel for bridge superstructures.

J. The study of the subject of alloy steels for bridgework and the actual use of nickel steel, Mayari steel, and silicon steel in bridges, thus not only reducing the costs of the structures but also permitting the building of far longer spans than is possible by the employment of carbon steel.

K. The perfecting of the suspension bridge, and its use for very long spans.

L. The study and development of the steel arch bridge, with resulting benefit to the esthetics of bridge designing.

M. The passing from pin-connected to riveted truss bridges.

N. Improvements in bridge shops and in methods of manufacturing steel.

O. Establishing sub-punching and reaming as a *sine qua non* for first-class bridgework, unless, of course, full-size drilling be adopted.

P. Greatly improved and more economic methods of erection.

Q. The inauguration and wide expansion of reinforced-concrete bridge building.

R. The perfecting of the pneumatic process for pier sinking.

S. The invention and extensive use of open dredging for pier sinking.

T. The invention of the steel sheet-pile, and its general employment for cofferdams.

U. The substitution of concrete for coursed-stone masonry in pier shafts, thus greatly lessening substructure costs.

V. The substitution of pavement, resting on waterproofed slabs of reinforced concrete, for timber in highway bridge floors.

W. Improved quality of concrete.

X. Greater attention paid to the matter of esthetics in bridge designing.

Y. An exhaustive study of the exceedingly important matter of economics in bridge designing and construction, and a start in practice on the application of the principles and facts established by the investigation.

Z. The establishment of several technical societies beneficial to the development of bridge building, outstanding among which are the American Society for Testing Materials and the American Railway Engineering Association.

WILLIAM MULHOLLAND

The builder of the Los Angeles Aqueduct. A pioneer in Western engineering

QUITE recently the question was brought up in this office as to the difference in cost of doing work at the present time as compared with past years. Analyzing this difference, a startling and unexpected result was disclosed in that while most materials of waterworks construction have advanced in price to, in some cases, double the cost of twenty or thirty years ago; the cost of completed work, such as pipe per lineal foot laid, or concrete in place per cubic yard and other bulky features, has remained practically the same, notwithstanding the great advance in the cost of labor, due to higher wage and shorter hours. This is mainly due first to a great improvement in the mechanical means of performing work; for example, even to the lay mind, the almost complete extinction and disappearance of such an individual as the hod-carrier must be noticeable. The prevalence of hoisting machinery about buildings and the utilization of mechanical methods of handling materials and particularly the greater availability of skillful men.

Let us cite particularly a few of the things that have tended to keep the cost of work down. Take in concrete work, the increased use of pneumatic tools in quarry work, rock crushing improvements, the development of elevators and mixers, together with transportation devices in the way of hoists, skips, chutes and the greater improvement of transportation facilities in the way of trucks, nearly all of which work was performed by hand or the use of animals and other laborious methods. In addition to this we have the improvement in tunnel boring, in the way of mucking machines, ventilating devices and the muck transporting facilities such as compressed air and internal combustion locomotives. Then again the pipe laying and the metallic structures of all kinds, such as tanks, etc., and the improved development of calking and cutting tools, acetylene welding and the like; added to which are trench excavating machines, steam shovels, pavement cutting tools and many other devices unused and unknown twenty or thirty years ago.

Not alone is labor more efficient, due to superior intelligence, but it is far more efficient due to easier conditions, such as shorter hours and more attractive employment because less laboriously performed. Indeed the writer is convinced that where formerly the major operations were performed by hand under physically exhausting conditions, the enthusiasm and morale of even the humblest worker on the job is improved by the efficient operation of labor-saving machinery.

MONTGOMERY MEIGS

Possessor of the unique official title, "United States Civil Engineer." For 50 years in the government service

I SHALL have to pass up to those who have had general experience in other lines the question as to what is the main difference between the engineering of today and that of fifty years ago.

I can, however, state shortly the difference between the methods of today and those that prevailed when the improvement of the Upper Mississippi was inaugurated in 1873, with which work I have been connected since 1874. In those early days hand labor was the rule, with mostly extemporized tools and such boats as we could get together.

At present we have compound condensing steel towboats, improved barges and houseboats for the men and even distilled water to drink, as Uncle Sam is as careful of the men in his employ as the best sanitary engineer could wish. Big suction dredges cut their way through the sand bars to assist navigation.

At first all the work was done by contract and a few men built up good plants of barges and towboats. It soon got, however, to the place where these contractors combined at the lettings and partitioned the different works among them, each contractor selecting the work he wanted and the others overbidding him. To correct this situation and to establish a fair price for the work several government-owned plants were established and the prices thus controlled. As time went on the fleet of contractors' boats began to disappear. This called for larger government fleets so that now practically all the work of actual construction is done by force account.

It comes about therefore that the public works of the country such as that under the engineers of the army is rapidly becoming socialized. With a trained corps of engineers, such as is the Corps of Engineers, U. S. Army, to do work by force account is natural and in the long run is cheaper, the only drawback being the intricate accounting system that was found necessary to protect the government from fraud. While the construction work has been thus absorbed by the government fleets the furnishing of materials is still let by contract.

JOSEPH R. WORCESTER

For many years a leading structural engineer in New England. A specialist in bridges and buildings

AT THE time I began work, skeleton buildings had not been invented. First-class or fireproof construction consisted of iron beams filled between with either brick arches, or, in rare cases, with arches of corrugated iron. The beams invariably rested upon masonry walls or cast-iron columns. This primitive construction required little engineering, but a few of the architects who designed the monumental structures employed consulting engineers to design the iron.

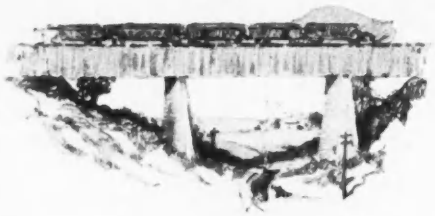
In those days the original drawings were very elaborately finished, with ornamental lettering and often with the iron members tinted blue. The originals were made on eggshell paper and tracings were used largely in place of prints.

The truss work of roofs, when of wood, was designed by contractors, many of whom had great skill in designing details. The iron trusses of large span were designed by a few remarkably able engineers then in active practice.

When skeleton construction first entered the field the architects were practically helpless, and were forced to call in engineering assistance. This was furnished to a great extent by the bridge shops, though one or two engineers in Boston in independent practice did some of this work.

The introduction of portland cement and reinforced concrete has come within the limits of my personal experience, and what a change that has wrought in building construction! There was a time early in the use of this material when those who had made a study of reinforced concrete ran away with the idea that they knew all about it. We jumped at the conclusion that the original method of using dry concrete and everlastingly ramming it was all wrong, and we went to the sloppy extreme. Now we are gradusally finding that we overshot the mark and did not know as much as we thought we did. However, in spite of our slips, we are gradually learning this art, and it has no doubt come to stay, until superseded by something better.

Architecture and engineering seem to be drawing closer and closer together. The number of firms which call themselves "architects and engineers" is constantly increasing. Sometimes this field is entered from the architectural end and sometimes from the engineering. This development has many advantages.



Bridge Engineering

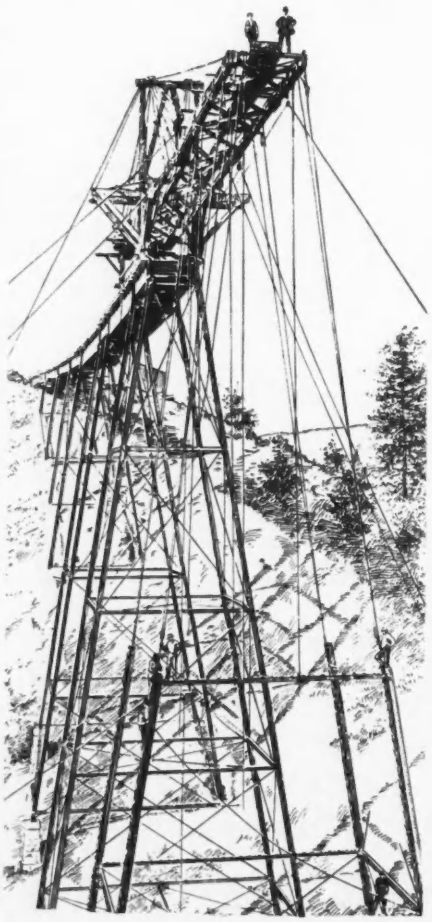
By Gustav Lindenthal

Consulting Engineer, New York

A RETROSPECT of bridge engineering during the last fifty years would present a record of unprecedented achievements, if space permitted. Only a few general facts and features can be given here. Let us consider what have been the distinctive features in the progress of design and construction of bridges in different countries during that period and what is their prospect for the future.

While bridge building as an art is as old as house building, bridge engineering as a science is hardly more than a hundred years old. The theoretical part had grown rapidly from empirical deductions and tests with models into the mathematical sciences of statics and graphics, which had already reached a high degree of perfection fifty years ago and have since then been developed so comprehensively that there is no field of stress analysis in bridge designing now left unexplored. What a rich mine of theoretical knowledge the literature of this field would appear to Telford and Stevensen, the first bridge engineers venturing to build long iron spans (1820-44), and even to Rankine, the great teacher of engineering (died 1872), whose theory of the stiffened suspension bridge came to America too late to influence the plans for Brooklyn bridge! Vast progress has also been made in the finesse of details and connections, in the testing and study of materials from which bridges are built.

Wood is passing out of use, with the indefensible wastage of our forests, as a material for bridges other than small or temporary structures. Fifty and more years ago wooden Howe trusses up to 200-ft. span (sometimes reinforced with wooden arches) and high wooden trestles were the prevailing pioneer types. Now the large sticks of lumber for them have become so scarce and dear that a Howe truss bridge would be a luxury, because more expensive than either an equivalent steel or concrete bridge. The latter materials have become dominant. Alloys steels, except for some parts in long spans, are, contrary to first expectations, little used in general bridge construction. Both theoretical and technological progress in bridge building have contributed to safety and economy.



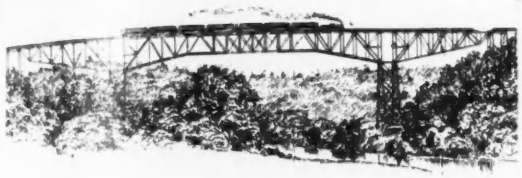
ERECTION OF BUFFALO TRACE VIADUCT

(From "Engineering News," May 25, 1889)

The oldest form, the stone arch, seems to have passed its apogee. Few large spans of that aristocratic type will likely be built, concrete being so much cheaper. The last and longest stone arch was the arcaded railroad bridge of 282-ft. span built in 1905 over the Isonzo river in Istria. That sterile region had for centuries produced highly skilled stone masons, whose work can be found all over Europe; with such labor it was feasible to erect the great arch to be self-sustaining in 48 hours. The bridge was destroyed in the war in 1916.

The greatest impetus to bridge construction in modern times came from the railroads. Since most countries have now all the railroads they can use, a decline in the number of new railroad bridges has already set in; but bridges for highways are being built in greater number than ever before, to meet the demands for improved road transportation with motor vehicles. All bridge construction, except for very long spans, has become standardized as to loads and stresses, quality of materials and workmanship.

Up to half a century ago, cast iron was yet used in large quantities for compression members in building framed bridges. At the International Exhibition in Vienna (1873) the writer admired a fine model of the Ohio bridge at Louisville, showing the large Fink trusses with cast-iron compression members and with tension members of wrought-iron eyebars. It was the largest and last structure of this type. About the same time a stirring discussion was carried on in the technical journals here and abroad on the merits of the types used in this country and Europe, the European



TYRONE CANTILEVER BRIDGE, KENTUCKY RIVER
(From "Engineering News" of April 8, 1890)

riveted girder type and the specifically American type of pin-connected trusses. Professor Winkler in Berlin, Professor Steiner in Prague on one side, and Charles Bender, Thomas C. Clarke and other bridge engineers in the United States on the other, were among the champions in that controversy, in which *Engineering News*, then in its babyhood, did not participate. Later came the controversy about statically determinate truss types as against those for which the stress ascertainment is based on the elastic properties of iron. American and European conditions for bridging and of fabrication and erection differed in so many respects that differences in methods were justified and finally came to be recognized. The American bridge types were adjusted to wide and capricious rivers, to long distances of transportation, high cost of labor and capital, the necessity of the structure earning an income as soon as possible, all of which made rapid execution necessary—and no type could surpass the pin-connected truss bridge in that respect. The erection of 300 to 500-ft. girders in a few days to be self-supporting appeared a wonderful feat to European engineers, accustomed to more leisurely methods.

But as bridge shop and erection facilities improved it came to pass gradually that pin-connected bridges lost some of their prestige because the more rigid riveted structures could be erected cheaper than pin-connected structures, except for very long spans. Economy of

LACHINE BRIDGE CONSTRUCTION

maintenance caused massive masonry and concrete structures to be preferred, for shorter spans, to the cheaper iron and steel bridges, which require continuous inspection and painting—a constant large expense.

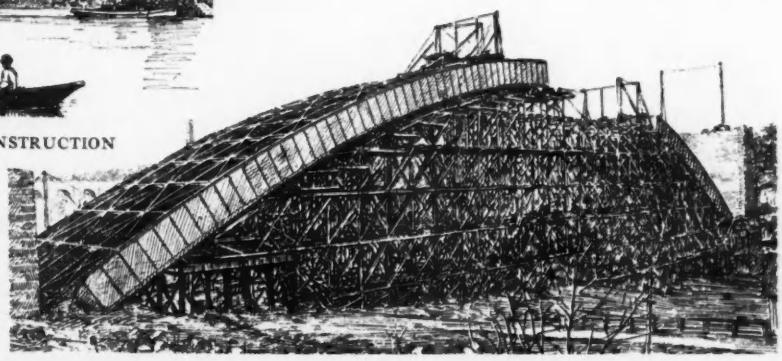
The last fifty years show the transition from wood and cast iron to wrought iron, steel and concrete as the principal materials for longer spans. Steel was first used in the St. Louis arch bridge, but as hard crucible steel, not suitable for smaller structures. It took ten years longer before a softer steel was recognized (1880) as preferable to wrought iron for bridges.

Two famous bridge structures in construction fifty years ago characterize the period; one was the great Brooklyn suspension bridge, which closed the period of massive high masonry towers, and the other the St. Louis steel arch bridge, which inaugurated the steel age for bridges. The plans of both structures evidence the desire for architectural dignity in contrast to unsightly commercial bridge types which had then commenced to acquire considerable prominence.

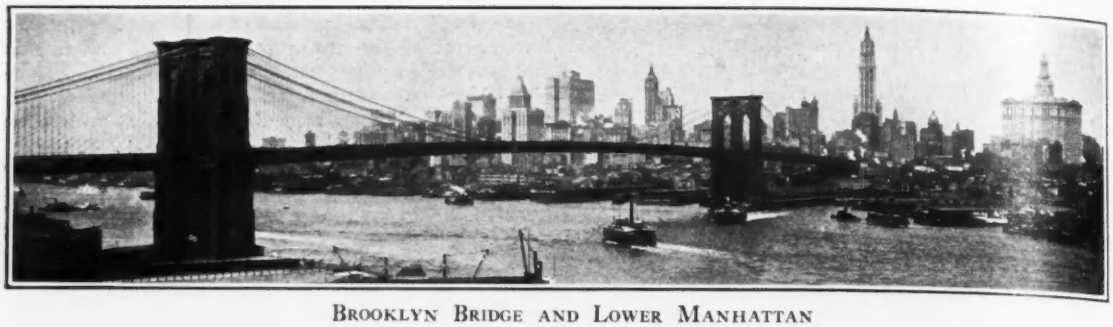
EIFFEL'S GARABIT ARCH

Iron, having little mass, is inferior to stone for esthetic forms. Iron towers would have been cheaper than stone towers for the Brooklyn bridge. The resources of the foundries, rolling mills and shops were adequate for their fabrication and erection. But fortunately solid granite towers were chosen, notwithstanding their greater cost. They are the largest and last of their kind. Their simple and rugged architecture give to the Brooklyn suspension bridge a distinction entirely missing in the two neighboring equally large suspension bridges built with steel towers, which appear prosaic and insignificant by comparison. If the Brooklyn bridge had similar iron towers it would appear in combination with its inferior suspended structure the shabbiest of all.

In the St. Louis arch bridge architectural beauty is likewise enhanced by the massive granite masonry of the river piers, flanked by the arcaded masonry approaches. The happy proportions of the three spans to each other, the middle span slightly larger and higher to produce a neat camber line for the roadway, the esthetically satisfying flat and slender arch ribs, and the altogether pleasing ensemble, evidence the thoughtful effort of the designer to create a magnificent structure. It also had many novel features of construction. It had the first and deepest pneumatic foundations in America, the diggers being exposed to over 50 lbs. of air pressure. The arch ribs have fixed ends and are of crucible steel, and were erected without falseworks by cantilevering. All



CONSTRUCTION OF WASHINGTON BRIDGE, HARLEM RIVER, NEW YORK

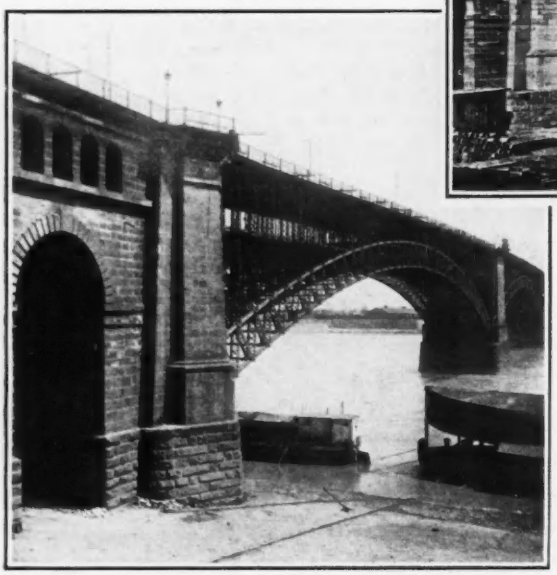


BROOKLYN BRIDGE AND LOWER MANHATTAN

material and work was tested with unprecedented precision.

The writer remembers with pleasure a call on Jacob Linville in 1874—Linville was one of the leading bridge engineers at that time and president of the Keystone Bridge Co., that had fabricated the superstructure for this bridge—and recalls the pride with which he exhibited and explained the plans and difficulties of this bridge, of which he and other prominent engineers had been severe critics during its execution. It was the writer's privilege to discuss later with Captain Eads and his loyal assistant Henry Flad the plans for this master work. Captain Eads, who had the true native engineering genius, and who originated and executed other engineering achievements, fully deserved the honor of the perpetuation of his name in the Hall of Fame.

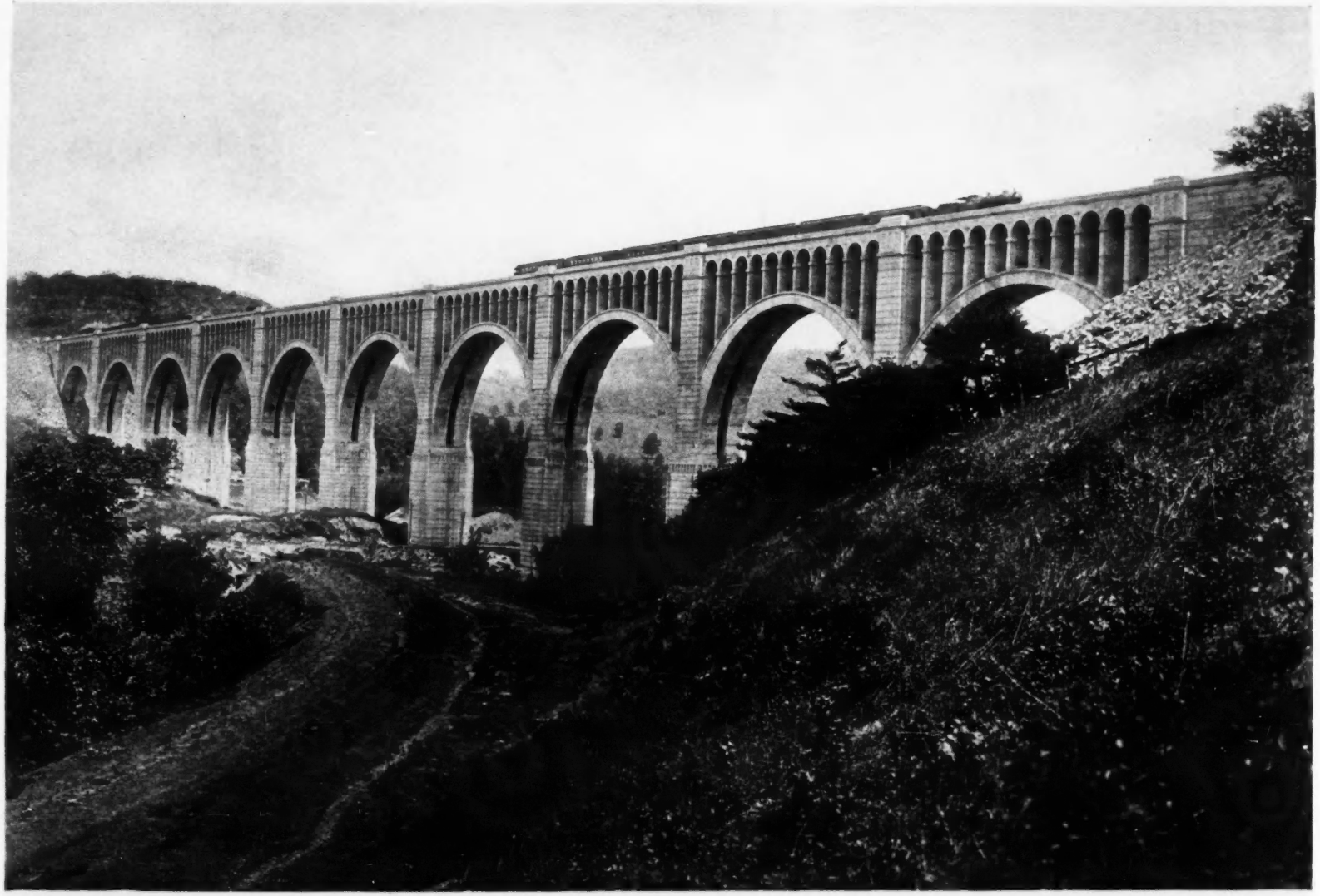
A word here on business morals of the past age. The Brooklyn Bridge was built with public money. It was the custom of the politicians of those days to send before election day a few hundred men to be employed as laborers, who were kept upon the payrolls until after the day after election. The engineers did not seem to know what to do with these voters, but they were satisfied to let them sit around and smoke their pipes, so long as they did not interfere with the regular workers. Was it any wonder that the bridge cost more than twice its estimated cost and took fourteen years for completion? It is only proper to say that in the last half century honesty in public work has greatly improved. The St. Louis bridge is an instance of an undertaking by private capitalists convinced of the great merit of the investment and confident of its ultimate profitableness. But for months after its completion railroad cars were ferried across the river as before. The company was deliberately forced into bankruptcy. The reward to the enterprising stockholders was the loss of their investment. The wealth created by genius and hard work went to a "great financier," all in perfect compliance with the



EADS BRIDGE IN 1874 (ABOVE) AND TODAY (LEFT)

tenets and tricks of law, as practiced by an old profession. Compare the reward of the sacrificing, idealistic builders with the reward of the disciples of high finance and practical business!

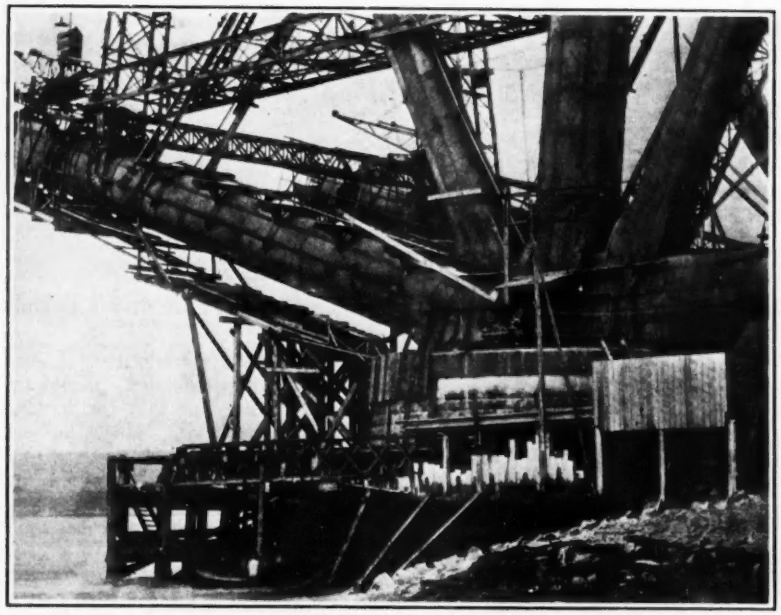
Let us now note the efforts made in Europe during the last thirty years to obtain architecturally pleasing bridge structures. The rivers Rhine and Elbe are crossed by numerous beautiful structures; stately arch bridges at Coblenz and Mayence; turreted truss bridges at Strassburg and Cologne. Several arched girder and cantilever structures show tasteful architectural treatment. A noteworthy effort to obtain esthetic structures was made in connection with two large bridges over the



Tunkhannock Viaduct on the Lackawanna Railroad

Danube in Budapest, one an eye-bar suspension bridge and the other a cantilever bridge. As the result of an international competition with prizes, over fifty designs were obtained, but in the end both bridges were built from designs prepared by the government engineers. These structures, while handsome, nevertheless leave the beholder cold, alongside the old chain suspension bridge (built in 1846) with its beautiful molded stone towers.

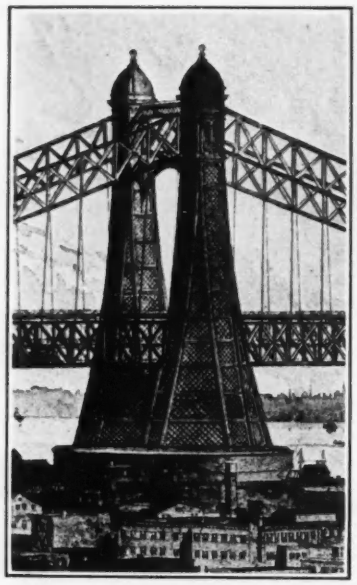
No wire suspension bridges of any size were built in Europe during the last fifty years. There is only one suspension bridge over the river Rhine. It is at Cologne and was completed in 1916. A determined effort was made to get a pleasing design, but it seems not to have been very successful. The cables are composed of plates and angles, riveted up into tension members, of which the horizontal thrust at the ends is taken up by box stiffening girders running from end to end, so that the anchorages resist only vertical forces. Its steel towers are plain and featureless.



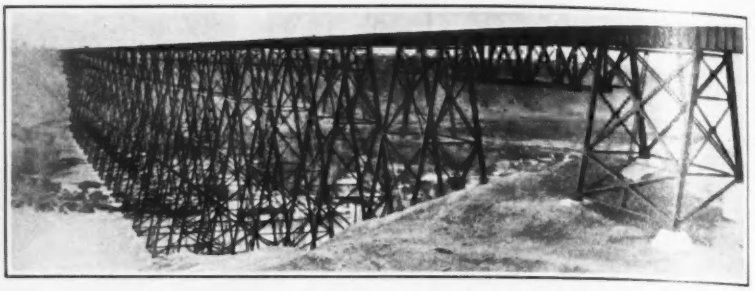
BUILDING THE FORTH BRIDGE

The Tower Bridge in London, a unique combination of suspension and bascule bridge, is one of the few bridges with stone towers in the last thirty years. The stone is only veneer over steel frames, yet the towers give a monumental character to the bridge in harmony with its historical background. That iron and steel is not a cold, expressionless material for towers in the hands of skillful architects is proved by the colossal and yet graceful Eiffel Tower in Paris. It plainly expresses to the beholder that its airy form is not intended to carry a heavy load at the top like a bridge tower—for that purpose it must have a stouter form, as for instance in the new Budapest chain suspension bridge, or as in the design for the massive double iron towers of the first plans (1888) prepared by the writer for the proposed Hudson River bridge, before the Eiffel Tower was built. Another original structure, by Eiffel, typical of French elegance, is the Garabit railroad viaduct in the south of France, a bold crescent steel arch over a deep gorge supporting continuous lattice girders in an unbroken line on latticed towers. The whole design is exquisitely adapted to the locality. American engineers would cross such a gorge with a trestle bridge. Just as in most French bridge designs for longer spans, elegance of form and neatness of detail are typical characteristics, so in many English bridge designs may be observed as typical a certain heaviness of form and a tendency of massing the stresses into fewer stout members rather than into a larger number of lighter members. In this sense the English type was exemplified even in the old long-span

OLD AND NEW SUSPENSION BRIDGES AT BUDAPEST



North River Bridge Towers
(1888 Design)



Lethbridge Viaduct on the Canadian Pacific; Highest Yet Built

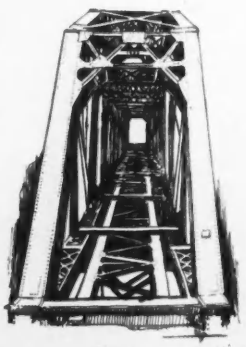
structures like the Britannia bridge and the Saltash bridge, but the same characteristic appears in the bridges of the last fifty years, like the Forth bridge, the Indus bridge at Sukkur and others.

Among the great bridges of originality and bold conception the Firth of Forth bridge in Scotland, still the largest and longest steel bridge structure, is remarkable. Its unadorned architecture is without an artistic silhouette. It expresses brutal power and strength, in full harmony with its conception as a riveted cantilever bridge. It was built up by methods of fabrication and erection more indigenous to iron shipbuilding than to bridge-building. The design was skillfully adapted to the local conditions; but it is safe to say also of this bridge, as of the Brooklyn and the St. Louis bridges, that for economic reasons it will not be duplicated. The only bigger span of the cantilever type, the Quebec bridge, followed American practice in its details of fabrication and erection.

These two cantilever bridges and the five bridges over the East River (three wire cable suspension bridges, one cantilever and the Hell Gate arch bridge) are the heaviest and longest-span bridges of the last fifty years. Of these the Hell Gate bridge, carrying four railroad tracks laid in stone ballast, was dimensioned for the heaviest known live-load—four lines of heavy locomotives on two trusses. A long-span wire-cable road bridge is now building over the Delaware River at Philadelphia. It will have the distinction of the heaviest steel wire cables (30 inches). Other long-span suspension bridges are proposed, one at Detroit and another at Nagasaki, Japan. The Sydney bridge in Australia, for which the contract has just been awarded, will be an arch design of 1,650 ft. span, a replica in form of the Hell Gate arch bridge, but for only half its live-load. The largest and heaviest bridge of all is proposed over the Hudson River at New York City, a suspension span of 3,240 ft. for a wide roadway and multiple tracks.

A most important development in bridge construction during the last forty years came through the use of armored or reinforced concrete. At first used only sporadically for small spans, the new material rapidly extended its field to larger and heavier arches. It has put into the hands of the bridge engineer a material with which he can in many cases build structures superior to those of steel in respect to durability, cost of maintenance and architectural appearance. Spans of over 600 ft. and high viaducts are feasible. Bridge architecture has gained much through this material.

WITH increasing skill and knowledge in the testing of materials and of their physical qualities, greater economy in the design of bridges has resulted. This may lead, under the stress of competition, to the temptation to attenuate the dimensions in bridge members, relying on supposedly accurately computed stresses, and upon supposedly sound material, insufficiently inspected and tested. So it will happen that in spite of the fact that modern bridge construction, having a strictly scientific basis, should with certainty avoid error and weakness, failures of important structures have occurred. Such was the collapse of the bridge over the Firth of Tay in Scotland near Dundee, when the loaded part of the bridge with a whole passenger train went down with great loss of life during a gale in December, 1879. The violence of the gale was blamed for it, but as a fact it was faulty design in the cast-iron bridge piers and wind bracing, which gave way, that caused the disaster. The new bridge which replaced it is safe against even more terrific gales. In the winter of 1876 occurred the collapse of the Ashtabula railroad bridge in Ohio during a severe snow storm, with great loss of life. The cause was found also in faulty details of design and faulty maintenance. The largest bridge failure of all was the collapse of the unfinished Quebec bridge in 1907 under its own weight on a clear day without notable wind, with a loss of 85 lives. The real cause was not defective material but defective design and ignorance of the real strength of a form of steel column which had not been tested.



Heavy construction of modern practice
Yuma Bridge, Southern Pacific Ry., 1923

Such bridge disasters carry a certain lesson to engi-

neers. In construction work there is often the pressure for lower cost. It requires courage of a high order on the part of the engineer to resist it. In this the engineering profession has a duty to perform. Bridges or buildings collapsing, pier foundations settling or washing out and dams going out, should not be laid up to Providence. Engineers are sometimes under the authority of laymen with whom financial considerations may seem more important than safety. If the pressure for cheapness comes from them, then the engineer should decline responsibility for the work. The economics of design that we hear so much about is in the direction of real scientific progress, but it must not be misused for gain and to cover up poor work. Competition of plans for ordinary bridge work under approved and fair rules has produced good results and is to be encouraged. But competition as practiced for many years, particularly for highway work, in charge of corrupt or ignorant public officials, had for years been a byword. Fortunately it is now getting less frequent.

STEEL ARCH BRIDGE IN THE NORTHERN FORESTS

The progress of bridge construction during the last fifty years is best exemplified on the American railroads. The railroads being responsible for damages had the best reason for having the best designed bridges. American railroad bridges of the last 25 years have not their superior in any country for quality of material and workmanship. Large bridges costing millions of dollars were comparatively few and will probably become less frequent in the next fifty years. The size of bridges never was limited by question of what we could fabricate, but rather by financial considerations.

Turning now from the last half-century to the next half and the future, what may we expect in the way of further progress in this branch of engineering?

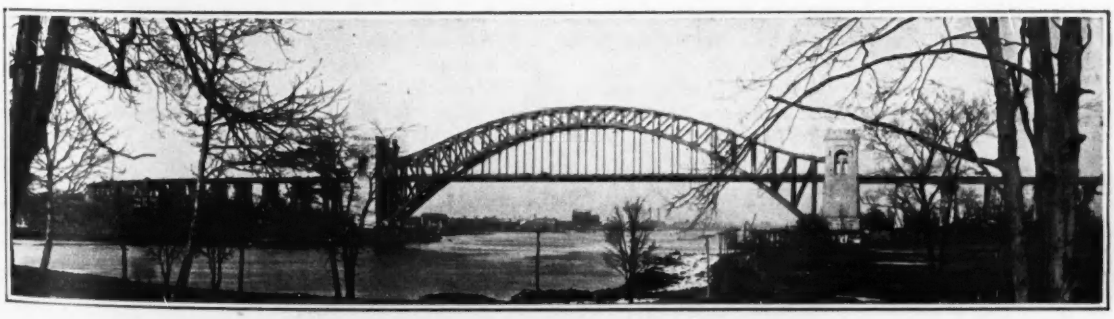
It is probable that the zenith of large bridge construction will be reached within the next fifty or hundred years, because of the increasing cost of iron and coal. Their prices have more than doubled in the last ten years. The iron ore beds will become exhausted long before the coal mines. The extent of both in all countries is now pretty well defined. The production of iron in large masses will diminish and become increasingly costly. There is no other metal of the same availability and strength to take its place for long-span bridges. With the exhaustion of the coal mines, the production and use of portland cement (which requires coal for calcination) will also cease. Stone bridges will then again be the only practicable lasting kind, as in the days before iron and concrete were used.

Bridge construction and bridge architecture will be to posterity in a certain sense a surer index of the progress of our present day civilization than houses, temples

MODERN CONCRETE ARCH HIGHWAY BRIDGE

or cathedrals appear to us of past ages. This will be so because the economizing of iron, when it becomes costly, will probably begin in bridge and structural construction before it begins in other kinds of construction. The large sources of energy in nature, coal, water power, wind, tides, heat of the sun, etc., can none of them be utilized without large masses of iron for the tools, machinery and power plants necessary for the conversion of these energies into power for the use of man—all of them more necessary than iron bridges, which may be then structures *de luxe*. Surely they would have appeared as such to the armored knights only one thousand years ago, when an iron armor was worth nearly half its weight in silver. Iron bridges, iron ships and railroads will then be curiosities. The colossal consumption of iron will have come to an end. In a span of time much shorter than that from Tut-ankh-amen to the present, steel bridges will probably have disappeared from the face of the earth through corrosion and neglect. Iron is a more perishable material, particularly in northern climates, than stone of which were built the Pyramids and the Greek temples and the wonderful Roman arch aqueducts—all in frostless, benign climates. These could be built again, but not iron bridges.

The creative genius of mankind, which now in this glorious age of iron is ascending to hyperbolic eminence in every branch of technical science, will leave few if any durable iron monuments to distant posterity. Among them should surely be, if possible, substantial large iron bridges that could be made to last several thousand years, if properly cared for in countries with stable, high civilizations. But who can look that far into the future?



Industrial Building Since 1874

By Charles T. Main
Engineer, Boston, Mass.

EIGHTY to one hundred years ago most of the textile industries were located on rivers where water was available for power and manufacturing purposes. As the transmission of power was mechanical, the buildings were close to the river, many times in narrow winding valleys, sometimes under a hill with little chance for light and air, or opportunity to expand properly.

With the outgrowing of the water powers and the cheaper production of steam power, some of the restrictions were removed, but it was not until the production of electric current and its transmission for power purposes that the buildings or the whole plant could be located with reference to the best requirements for construction, with a view to proper expansion, and the other vital elements of location with reference to operatives and transportation.

These old buildings were narrow, usually 40 to 60 ft., most of them having stone walls with wooden columns, and floors of joisted construction, such as is now customary in the floors of dwellings. The walls were heavy and the floors were usually light. There were often wooden bolsters over the columns with no pintals, and, being wood from top to bottom, the shrinkage at the columns caused the floors to sag. Sometimes the columns were very small and of cast iron.

The stories were low, approximately 10 ft., which afforded very little head room for shafting and belting, and not much space above the machinery for ventilation.

The top floor usually was hung by rods from the roof truss, the roof being either pitched or mansard. This allowed the omission of columns in the story below.

The windows were small, thus giving very poor natural lighting even for such narrow rooms. The openings were frequently only 20 per cent of the wall area. The stairways were usually of wood, inside the building, and not enclosed. Sometimes they were located in towers outside the main building, the favorite type being the dangerous spiral form winding around a column, with tapered treads very narrow at the columns.

There was no system of ventilation, the only fresh air coming through the open windows.

The toilet arrangements were of the crudest, no provision being made for sanitation and no real separation of men and women.

Artificial lighting was done by kerosene lamps, more or less clean, and always a source of danger.

The main driving belts were inside the mill, running up through belt holes in the floors, unprotected, and forming one of the serious fire hazards and personal risks.

The means for fighting fires were very meager; water barrels and buckets were the usual means. Automatic sprinklers were unknown. Perforated pipe sprinklers were in some mills fifty years ago. Some of the larger mills had hand operated fire pumps.

Very few safeguards were installed to prevent accidents to the operatives.

Building laws had not been thought of, and any kind of a structure could be erected outside of a city. No laws had been enacted with reference to the sanitation and other conditions.

Conditions were as they were, not intentionally, but largely through carelessness and lack of knowledge of the fundamental principles of health.

These mills were poor fire risks and insurance rates were high. In some exceptional cases the insurance companies would not take the risk. It is astonishing, however, that some of these poor risks seemed to be immune from fire. Old wooden buildings, with floors soaked with oil, of light joisted construction, with hundreds of kerosene lamps, stood for a great many years, in spite of so many elements of danger.

THE EFFECT upon the operatives of these poor conditions of light, ventilation and sanitation, during long working hours, together with frequent accidents, was not conducive to good health or high morals, or initiative and stamina, or to the greatest possible quantity and quality of product. The fact that the better operatives will leave the old concerns, and seek employment in the newer ones, with more modern facilities and conveniences, shows that there is a desire for better conditions, and that a better grade of working people can be obtained and kept in the better plants.

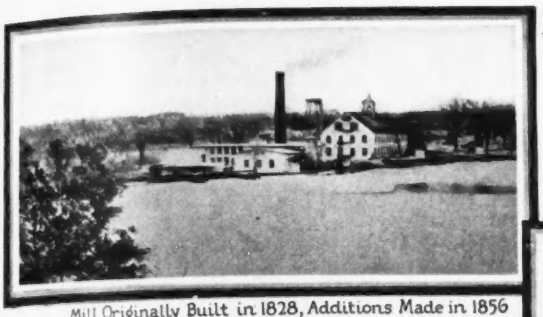
These conditions of construction and management had not greatly improved up to 1870, about fifty years ago. At that date the recorded average loss, as given by two of the Factory Mutual Fire Insurance Companies, was 61.4c. per $100. This then relatively low rate was reported as being due to the improved construction and proper observance of rules for cleanliness and new methods of extinguishing fires.

About this time, 1870, began the intensive attempt to educate the public and manufacturers in the idea of the so-called "slow burning construction."

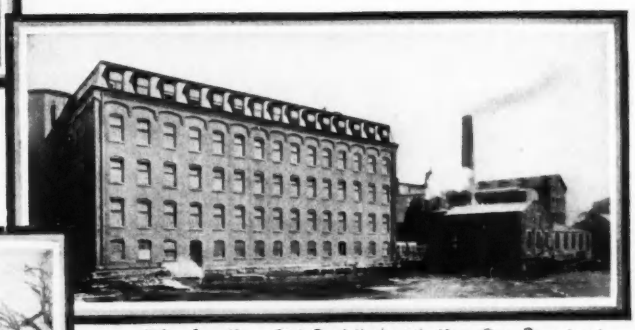
The slow burning type of construction consists of brick walls, floors of large timbers, spaced approximately on 10-ft. centers, but actually to suit the machinery to be installed, with heavy floor planking and a hardwood top floor, and with wood columns spaced one in each bay, lengthwise of the building, and about 23 ft. across the building. This latter spacing also was determined by the machinery. The roofs were built in the same manner as the floors, except that they were slightly lighter, and were pitched about ½ in. per foot, and covered usually with tar and gravel.

In the best designed buildings, after this period, the stairs were located in brick towers with straight runs and half landings, and the main belts were put into brick towers or races. The openings to the stairways and belt towers were provided with tinned doors.

A Half Century of Development *in* INDUSTRIAL BUILDING



Mill Originally Built in 1828, Additions Made in 1856 and 1907, Recently Taken Down



Fifty-four Year Old Building with Non-Fire-Resisting Mansard Roof

Mill at Right 75 Years Old with Modern Hydro-Electric Plant Addition at Left

Country Mill Supposed to be 62 Years Old

Center-Modern Mill Type Building

Above-Interior of Same Building

Left-Modern Reinforced-Concrete Mill

Above-Interior of Concrete Mill

The automatic sprinkler came into use about this time, and the combination of slow burning construction and sprinklers reduced the fire risks enormously.

These buildings were usually wider than the old type, usually about 75 ft. wide, and sometimes 100 ft. But these widths were later increased to over 125 ft. and sometimes to 145 ft. to meet the requirements of modern machinery.

The story heights were approximately 13 ft. for 50-ft. width, 14 ft. for 75-ft., 15 ft. for 100-ft., 16 ft. for 125-ft.

The windows were larger and extended up to the ceiling and the light was thrown into the middle of the room.

THIS type of construction has been in great favor since about 1870, and during that period the principles of construction have not changed materially, but the details have changed somewhat. The principal changes have been in increasing the size of the windows until now the glass area in the walls is 50 to 70 per cent of the wall area, in the use of prism glass to throw the light into the center of the room, in painting the inside a white gloss to improve the lighting, improvements in ventilation of rooms formerly filled with dust or fog and lacking in a supply of fresh air, better artificial lighting, more careful planning of exits, installation of elevators and escalators for the operatives in some of the high buildings, and all the things which modern laws require for the safety and comfort of the operatives.

As machinery has become larger and heavier, and the spans of the beams have been increased to accommodate the machinery, and at the same time the procurement of the best southern pine has become more difficult, steel I-beams have come into general use for floorbeams, supported by wood, cast iron or steel columns.

In the latter part of the last 50-year period, buildings of structural steel, with the steel more or less protected from fire, and reinforced-concrete buildings have been built for manufacturing purposes. These, within the fire limits of larger cities, are required to be constructed of non-inflammable materials, with all steelwork fireproofed.

Great advances have been made in the general character of buildings, and in the economic use of materials. The greatest advances are in the use of steel and reinforced concrete. The latter had not been used much, if at all, in building superstructures prior to 1890. Concrete has replaced stone in foundations in nearly all work. Its character and mobility have made possible the construction of many structures not possible with stone alone.

Stairways and elevators are usually in separate masonry or fireproof towers, outside the manufacturing floor space, with openings protected by fire resisting doors. Toilets are in separate rooms with adequate ventilation.

About 1900 the transmission of electric current for power and the installation of motors were established, and from that time on the location of a plant could be made with more particular reference to the other requirements than power, and this has contributed to construction with reference to future growth, and better consideration for light, air and comfort.

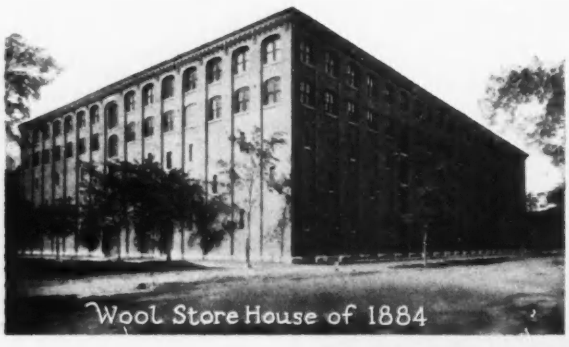
The electric motor drive has also improved the room by making possible the elimination of the large driving belts or ropes by motors driving a group of machines like the four frame drive, or by individual drives, thus eliminating much of the shafting and overhead belting.

During all of this last period careful attention has been given to all items of construction and operation which are a fire risk. The Factory Mutual Fire Insurance Co. makes systematic inspections, followed by report with recommendations for improvements, with the result that the average loss by fire from 1914 to 1924 is only 4.4c per $100 of insurance, and the cost of insurance only 8.5c as against 36.3c per $100 fifty years ago. The greatest reduction in the losses and cost of fire insurance occurred in the period from 1874 to 1904.

The same period marks the greatest advances in construction, fire protection and prevention devices, and methods of eliminating conditions dangerous to life.

THE general effect of improved factory conditions cannot be otherwise than beneficial to the health and morals of the operatives. Whether they are any happier than they were fifty years ago is a question.

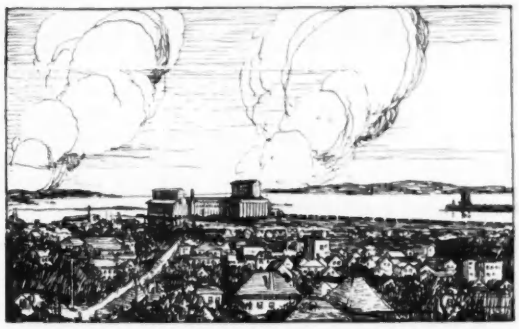
In looking back some forty years, I feel sure that the great bulk of the operatives were fairly happy and contented with their surroundings and positions. At the present time with so many people trying to do things for them that they could do better for themselves, and with so many diversions there is great uncertainty and unrest. It is fortunate that those in control of the industries realize this state of affairs, and are making progress on the problem of making the operatives feel that they are a part of the industry, and that they will be granted their fair share in the conduct and returns of the industry.



Wool Store House of 1884

Cotton Store House of 1924

PORT ARTHUR IN 1874



PORT ARTHUR TODAY

Fifty Years of Canadian Engineering

By H. K. Wicksteed

Canadian Northern Ry. System, Toronto, Ont.

THE HALF-CENTURY which has gone by has seen an extraordinary change in Canada. As we know it today Canada had only come into existence a half dozen years before, and had been known as British North America, and the name Canada applied only to what are now the Provinces of Ontario and Quebec, then called "Upper" and "Lower" Canada. On the Atlantic coast were two colonies, Nova Scotia and New Brunswick, and on the Pacific another, British Columbia. In between Upper Canada and British Columbia was an enormous stretch of wilderness ruled over by the Hudson's Bay Fur Trading Co., inhabited by some roving bands of Indians, and dotted over with a few dozen stockaded trading posts manned by a handful of white men and half-breeds. Only at one point, Fort Garry on the Red River, was there any fixed settlement and some agricultural industry, organized by Lord Selkirk sixty years before. The scheme of welding all these different areas into a concordant whole was a very bold one, the more so as even in a social sense the elements were somewhat variant and even antagonistic.

Nova Scotia and British Columbia were centered about the naval stations of Halifax and Victoria, and their social leaders were intensely British in sentiment and conservative in the extreme. Ontario was largely settled by United Empire Loyalists, refugees from the United States, and also British, but not by any means so conservative; and Quebec was very largely composed of a quite different race, the original stock of Norman and Breton French who had peopled the country a couple of centuries before, and called it New France. These were passively British because they had been well treated after the conquest, and allowed to live as a separate community and race to a very large extent. With the Hudson Bay Co. the question of elimination of its rights was largely a matter of business. It was a trading company, and out to make money, and its claim was settled on this basis. There was some trouble with the Red River settlers, but they were few in numbers.

It was evident from the first that in order to govern such a territory properly some better means of communication must be provided than the birch bark canoe and Red River cart. The center of population was far to the East (Ottawa was finally chosen as the capital) and for delegates to travel from British Columbia or even from Nova Scotia to take part in conferences, especially in winter, once a year or oftener, was out of the question. Much less was it possible to have a satisfactory interchange of goods and merchandise, and here was materialized the idea of the Canadian Pacific Ry. The Intercolonial was an older one which had been looked into by the Imperial Government many years before as a military necessity demonstrated during the War of 1812, but even it did not take definite shape until confederation, and was completed at the beginning of our half-century.

The Canadian Pacific was a very different matter. Canada is a country of magnificent distances, and transportation had been from the earliest times its principal problem. It was a somewhat different problem from that of the United States, for the latter had confined its attention to the opening up and development of its own country, and its first transcontinental was in conception largely the result of the development of California and the West, subsequent to 1849. Population and trade were waiting for the Union Pacific, but in Canada's case there was no such population or trade.

BUT there was something in the case of the Canadian Pacific which there was not in the case of the Union Pacific. Columbus had started out to find a route to Cathay, to get east by going west. The American continent blocked him. Jacques Cartier and others tried the same thing farther north, and the discovery of the St. Lawrence, and the founding of New France was the result. Verendrye put in his whole life in the same quest for the Western Sea overland. Hudson, Frobisher, McLintock, and Franklin tried farther north for a route which they now called the "Northwest Passage."

England had now great interests in the East and the problem was of great importance to her. Franklin's disaster ended the search by sea, but the idea would not die, and in 1859 the Hind & Palliser expedition was sent to report on a route across the plains and the approaches to the mountain passes of the Rockies. Mackenzie, Fraser and Thomson had already determined the courses of the great rivers of British Columbia. The most remarkable expedition of all perhaps in that it was a private enterprise conceived by a couple of Englishmen, was that of Milton and Cheadle. Their story is told in a book entitled "The Northwest Passage by Land" published in 1863, and it is prophetic.

These gentlemen did not venture to think much about railways; they were, aside from sport and adventure, looking for a route overland to the Cariboo goldfields of British Columbia, and from choice they took the Yellowhead Pass, and through an accident missed the direct course west and turned down the valley of the North Thomson to Kamloops. Surveys and explorations for the Canadian Pacific Ry. as such were commenced in 1870, and the first sod was turned at Fort William on Lake Superior in 1875.

I have dwelt on the history of Confederation, and of the Canadian Pacific, which was a direct sequence, because they were the beginnings of Canadian engineering properly so-called. There was, of course, much engineering work done before this epoch, some of which I have outlined, but it was done largely by English engineers. The Grand Trunk, for instance, was almost entirely the work of Englishmen imported for the purpose, and the construction of the Intercolonial Ry. was of pretty much the same general pattern with regard to English construction.

SPIRAL TUNNELS IN CANADIAN ROCKIES

Perhaps it was the birth of a national spirit, perhaps the feeling that even the lower grades of assistants should have some technical knowledge and should be recruited from the country through which the road passed, possibly it was even then realized that the English standards were not in all particulars those best adapted to a new country, but this same period of the early seventies saw the birth of the present School of Applied Science in McGill University and soon afterward of a similar one in Toronto. Certainly the movement was opportune, for while in Sandford Fleming the Canadian Pacific had a chief engineer of great breadth of mind and foresight, the same can hardly be said of many of his imported assistants who displayed a culpable conservatism, and a lamentable incapacity for adapting themselves to new conditions of topography, climate and sociology. The younger men picked up the modified methods and ideas which had been in process of evolution in the United States for a generation or more, much more readily. They evolved themselves modifications and improvements, but I think none of us will ever forget what we owe to Trautwine and Vose, and later to A. M. Wellington and *Engineering News*.

The construction of the Canadian Pacific involved only a few problems of great magnitude, but the scheming out of the best route was a very serious undertaking indeed, because so much of the country was unknown, and not even roughly mapped. Curiously enough, the most problematic portion was that north of Lakes Superior and Huron within a few days' travel of older Ontario, a country of rocks and swamps and innumerable lakes and dense forest, through which some sort of practicable line could be obtained almost anywhere, but the best route for a transcontinental railway which was to bring the far East into closer touch with the heart of the empire was a very different matter, and Mr. Fleming recognized it as such. This unbroken wilderness extended for one thousand miles, and was so formidable that it was termed the "Great Barrier." The prairie section was comparatively simple, one could see ahead, and through the mountains there were less than a half-dozen practicable passes leading to an even fewer number of river valleys affording routes to the sea. There was room for an enormous amount of careful instrument work, but on location rather than reconnaissance.

Mr. Fleming chose the Yellowhead Pass as most suitable, and never wavered from it; time has fully vindicated his judgment. Some ten years went by and things had moved with apparent slowness. The prairie had been connected with the Great Lakes at Fort William, and a few miles built in British Columbia. The change of policy from one of public ownership to that of construction by private enterprise was one of political expediency, rather than of engineering, but it had important engineering consequences. Mr. Fleming's aim was an imperial road. Van Horne, acting for a financial syndicate of not unlimited resources, had to build a road as cheaply as possible, and within a specified time, which was none too long for the task. He adopted the shortest route which the map could show, and went at it. At two points he ran up against new problems.

One was a location on the immediate shore of Lake Superior, the other the crossing of the Selkirk range in British Columbia. The first was solved by Canadian engineers; for the second an American, Major Rogers,

was called in. The solution involved grades of 2.2 per cent. and other expensive features, afterwards superseded by the 5-mile Connaught tunnel, but it must not be assumed that the choice was a gigantic blunder, as has been sometimes said. To build a road through the mountains entailed one first across the plains, some 900 miles. The route of this had to be decided offhand, and Mr. Van Horne decided, and took chances. Time was all important. Similarly with the Lake Superior section. Even with the knowledge he already had, the line of the Canadian Northern took some four years of the writer's time to lay down, and over a year to build. Such an allowance was out of the question in the case of the Canadian Pacific.

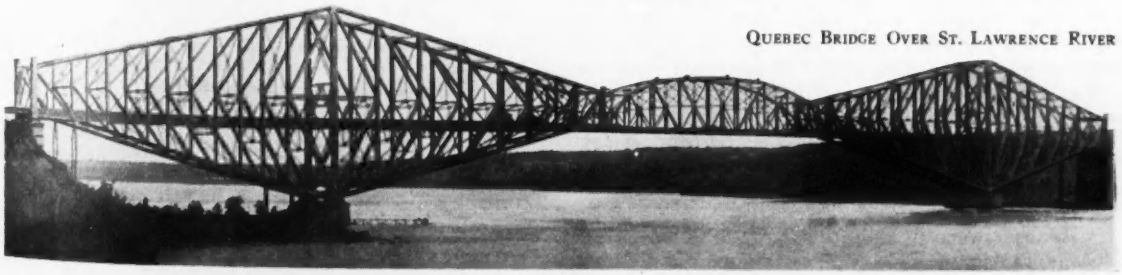
THE Canadian Pacific and the Grand Trunk were the training schools for many Canadian engineers, and in those days they were almost all railway men. A lull came in the nineties, some of them had hard times for a while, and drifted into other employments. Transportation was still the problem, and, relieved of the railway, the government took up the enlargement of the St. Lawrence canal system. After a hard struggle for ten years, the enterprise of the Canadian Pacific Ry. began to bear fruit. The prairie received a large influx of population, and demonstrated its capacity for production. Confidence was established, and capital was attracted. Still the cry was for cheaper and more extended transportation facilities to meet the needs of western expansion, and railway building commenced afresh. The romantic enterprise of the Canadian Northern was started as a complement to the Canadian Pacific, and by the beginning of the century assumed the attitude of a competitor, but by this time there was a large number of trained engineers in the country, and other employment opened up for them.

The electrification of urban railways came in 1890, with Toronto one of the first, and partly as a result of this and the demand for power to operate them came the development of water power, first and naturally the enlargement of those dependent on the Welland Canal, then those at Niagara itself. In Quebec there were the several developments now consolidated in the Montreal Light, Heat and Power Co., and a little later the wonderfully successful Shawinigan power development on the St. Maurice. Canada claims some twenty millions of potential horsepower, and with the total absence of coal deposits, except in the West and the far East, lays great stress on the value of these powers to the present and future generations. Three millions is now developed.

The present century has also seen a great development in mining in Northern Ontario, the Sudbury district is well known now as the producer of most of the world's nickel, and a later development is the silver of Cobalt, and still later the gold of Porcupine. It is notable that in older countries, even in the United States, the railways came into existence as the servants of the industries of mining and agricultural development. In Canada the railways came first, and paved the way for industries.

It is perhaps little wonder that seeing what had been effected through the medium of railways, Canada should have been super-optimistic and overdone the building of them. Certain it is that it has engaged the attention of engineers until recently, almost to the exclusion of other branches, and most of the great works of the last fifty years have been parts of them,—the Quebec Bridge with the longest cantilever span in the world, the Connaught tunnel and Lethbridge viaduct of the Canadian Pacific Ry., the Montreal tunnel and Frazer Canyon grading of the Canadian Northern, and St. Clair tunnel of the Grand Trunk. Other works rendered possible by them are the great Gouin dam of the St. Maurice, and the power developments upon that river and the Saguenay and Ottawa. Indirectly fostered by them are the Welland Canal, the harbor developments at Montreal, Halifax, St. John, Port Arthur, Fort William and Vancouver, not to mention the irrigation works of Southern Alberta and the many municipal problems of Vancouver, and the cities of the Western plains.

THERE is still much to do, and probably problems of a different nature to be solved in the future in the vast country to the North. In the immediate future is one of paramount importance just beginning to be understood, that of reforestation. The forest has been the support of Canada for many generations, first as the home of furbearing animals, next to the early settler as his source of fuel, building timber, fencing and shelter, to the lumberman as his stock-in-trade, to the miner as making his underground operations possible. Now we are beginning to realize that the forest is a conserver of streams and water supply, and has important influence on climatic conditions, yet it has been systematically butchered and wasted for at least fifty years. Nature herself is wasteful in her methods, primitive man is certainly no better, but in this twentieth century we boast that we are getting more and more the upper hand of Nature, and can "control her great forces to our use and convenience." All we have done is prohibit wanton destruction and allow nature to resume its course, but nature is slow and man greedy. Without some help to nature, ultimate destruction of the forest is certain.



QUEBEC BRIDGE OVER ST. LAWRENCE RIVER

Fifty Years of Contracting

By F. L. Cranford

President, Associated General Contractors of America

CONTRACTING in its various forms has been the method by which the great bulk of construction has been performed. Its history for the past fifty years has been a development from the practical to the scientific. The successful contractor of fifty years ago often developed from the mechanic, who had proved himself a capable and efficient handler of men and whose experience gave him a practical knowledge of many engineering problems which he expressed by some rule of thumb. To the construction executive of today, knowledge of men and of the complicated sequence and co-ordination of factors of design, purchase, transportation and assembly, of methods and of engineering, is essential in the more complicated and vastly greater units of construction work.

Fifty years ago men were plentiful and "main strength and awkwardness" performed a vast amount of work very efficiently and with surprising economy. As a boy I knew many of the contractors whose experiences carried them back fifty years and was very familiar with their rugged, forceful character, their intense application to their work, and their many virtues though they were not unfamiliar with the vices and met and dealt with the world as they found it according to the standard of the times. The foundation of the work which is now the permanent wealth of America was laid by these men. Their profits as a rule were directly in proportion to the amount of work that could be gotten out of their men throughout the long day.

Their equipment was simple and meager, for their work was done mostly by hand. Their fields of operations were more localized and their contact with the owner more direct. Large engineering construction consisted mainly of railroad construction and bridges, out in the open country, across the plains, in virgin territory, where Indians possibly were less troublesome than the latter day politician. They were blessed with a strong and enduring type of labor, the kind with a strong back which could stand long hours and work hard during those hours. The supply exceeded the demand. The immigrants of the day were from northern European stock and were rugged types of men. These contractors' methods of doing business were crude, and their offices were under their hats. Their methods of getting business were also crude, and conditions often necessitated their being politicians in order to get business. Competition was less, labor was humble and plentiful and unorganized, and the jack-of-all-trades was a prominent and important factor on every job.

TODAY all this has been changed. The development of the labor union, the change in the type of immigrant, and the present peak of activity in construction have created a situation where the number of skilled workmen is inadequate to the needs of the hour and have emphasized the social and racial restrictions which influence our own boys to seek the "white collar job" as against manual labor. The stigma of joining a gang of foreigners is very real.

The elements of contracting are: (1) Soliciting, (2) financing, and (3) constructing. They were the same in 1874. Ways and means have changed, conditions have changed and, in a measure, the manner of thinking has changed, but contracting in 1924 is not different elementally from contracting in 1874. The half-century has grown a rival—force-account construction—but, except to note the incursion of this disturbing element, a record of contracting in fifty years is chiefly a recitation of changes in practice. These are epochal. They are indicated best by analyzing roughly the elements of contracting:

I. *Soliciting*—getting the job: (1) Establishing good will; (2) forms of contract; (3) estimating.

II. *Financing*—getting the money: (1) banking; (2) securities and insurance; (3) accounting.

III. *Constructing*—doing the work: (1) Materials; (2) transportation; (3) equipment; (4) labor.

In general in 1874 the contractor held a more familiar relationship with the owner and engineer than he does now. The general contractor did little other than local work and the owner was his associate in the business and political affairs of the community. This personal relationship still prevails to a considerable extent in lesser operations in small communities and in contracting for the railways and big industrial organizations having a continuous construction program, but in general the relations of contractor and owner are essentially impersonal.

CONTRACTORS have become construction organizations. In turn owners have become large commercial or industrial organizations or departments of public works. Contractors go farther afield for work and owners reach out over a wider territory for competitors for the work they have to offer. Again a large part of public work, by law, has to be given to the responsible contractor who asks the lowest price. Only an impersonal business relationship is generally possible under these conditions and this puts upon the contractors the task of establishing on a different basis than personal acquaintanceship their reputation for responsibility, skill and integrity. Good will is a business growth rather than a personal possession, and its cultivation calls for all the aids of publicity, association activity, participation in public affairs, etc., through which, in addition to service, modern business gets prestige.

Contracts have developed no new forms. In 1874 the lump-sum contract prevailed. Today the unit-price contract, in general, prevails. The cost-plus contract has secondary but not an unimportant place. It received its most familiar expression in the construction for the world war and here, illogically and unjustly, it was the cause of condemnation of war officials and war contractors. With the unit-price contract, complexity of form came. It increased with the cost-plus contract. Refinements in materials and workmanship developed more complications. Then laws began to multiply. The practice increased of putting the burden of responsibility upon the contractor. Agencies for doing public work multiplied and each created its special form of contract. The complexity and confusion resulted in a situation which both contractor and owner at last comprehended was impossible and for two years active efforts have been made to codify laws and to standardize forms of contracts and particularly to provide in contracts for a fair determination of responsibilities and risks between contractor and owner.

As in other business, price is a large factor in marketing contracting service. Estimating the costs upon which to base price has grown more complicated with the increased complexity of contracts and with the elaboration of the service of structures. We must not forget the last factor. The building, for example, of 1874 rendered far more simple service than does the building of 1924. With this extension of particularity in estimates, came the necessity for greater precision because of the greater totals involved and more because of increasing variableness in materials supply, labor conditions and transportation service. Indeed, today, estimating has become almost the most intricate technical process in the contracting business.

With the increased complexity of his task there have developed two outstanding aids in the estimator's work: (1) Cost accounting and (2) quantity surveying. Contractors' cost accounting, in the sense of cost analysis to determine prices, is wholly a development of the period from 1874 to 1924. Quantity surveying has had its high development in Great Britain rather than in America, but all its real growth has taken place in fifty years and in the United States all has taken place in not much over a dozen years.

Contracting finance has undergone no fundamental change. Banking, bonding, insurance and accounting are the elements in 1924 as in 1874. Naturally contractors' negotiations with banks have grown in magnitude; the processes of getting bank credit are, however, no different and are those which all business follows.

The big developments in contracting finance have been surety bonding, insurance and cost accounting. Corporate surety bonding is only about twenty-five years old. Personal suretyship was the normal guarantee of contract performance in 1874 and for many years after. Formerly only the performance of the contract was guaranteed. In most states the laws today require bonds guaranteeing in addition all materials and labor bills.

Due to the extension of liability and the large growth of construction operations and because of obvious limitations and defects of personal suretyship, the growth of corporate surety bonding has been widespread. It has enormous power to stabilize contracting and is failing to use it. Co-operation with engineers and contractors and surety companies to improve this situation has recently begun. Insurance, aside from surety bonding, has increased the magnitude of its operations and has been extended in many new directions since 1874.

Plain business bookkeeping was about the only accounting done by contractors in 1874, and indeed until within the last twenty years. Cost keeping as an accounting operation does not date back of 1890. Today in its highest form it involves records and measurements and their technical evaluation in cost or performance units which make it a veritable gage of job economies. Utilized as it can be, cost keeping is one of the most powerful helps in contracting finance which fifty years' experience has developed.

MATERIALS, transportation, equipment and labor are the elements which enter into contracting as construction. There have been epochal changes in each since 1874. In each the constructor today deals with a thing so radically different as to be without the bounds of speculation at the birth of the half-century which is being considered. So multitudinous have been the changes that only the most important may be mentioned.

While the contractor today works with few if any materials unknown to the contractor of 1874, there has been a great change in their character and the comparative amounts used. Obviously there has been a vast increase in the absolute volumes, and coincidently a great multiplication of commercial producers and dealers. Let us note the changes. The natural cement industry has risen and declined and been replaced by the portland cement industry of far greater volume. The

rolling mill and fabricating shop have changed their product from wrought iron to steel. The production of bitumens and tars, relatively insignificant for construction in 1874, have increased until they constitute a principal material for streets and roads and in general construction for roofing and waterproofing. Vitrified clay products, paving brick, sewer pipe and building tile, all come within the industrial development of half a century. With the development of cement there has come the crushed stone quarryman and the sand and gravel producer Lumbering and quarrying have not altered essentially. Production of non-ferrous metals for construction has developed almost entirely, with electrical construction, in fifty years. The list need not be extended.

It is with far different materials than in 1874 that the contractor works today. Concrete and steel, clay products and bitumen products are the essential materials of engineering structures. Stone has become largely a material for finish and embellishment and wood a material for finish and for uses subsidiary to construction as falsework and forms. They were primary materials of structures in 1874. The change in and development of construction crafts to correspond to the new materials are an outstanding characteristic.

IN 1874 the railway, the waterway and the wagon and cart were the only means of bringing construction materials from the market and of haulage on the job. The railway continues to serve the contractor between market and job to a greater degree than ever, but to its service have been added the electric railway, motor trucks and tractors and industrial railways. For less general service there have come the cableway, the cable tramway and conveyor systems. In job haulage, these new means of transport have revolutionized practice. There have come into general use new powers, the gas engine, electric motor and compressed air Special purpose equipment as trench excavators, power backfillers and paving mixers have developed. There has been great improvement in the portability and mobility of equipment and of machine design and fabrication. The fundamental fact to observe here is that construction in fifty years has changed largely to a machine process and the contracting business today comprehends mechanical plant selection, operation and maintenance of striking magnitude.

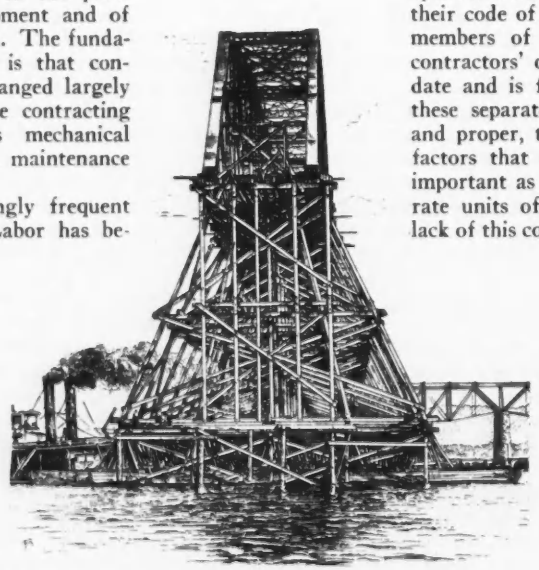
There have been increasingly frequent periods of labor scarcity. Labor has become highly variable in cost, in efficiency and in quantity. It is of a far different disposition than in 1874. Perhaps we go far enough when we say that construction is in the same situation in respect to labor as is all industry. It has before it the task of all industry of improving the situation and this is among the most complex tasks of society. The progress it has made through organization work to encourage apprenticeship and reduce seasonal employment has been noteworthy and indicates a purposeful stride forward in the great task.

Indeed it is perhaps the highest accomplishment of contracting in fifty years that it has learned to organize for co-ordinated co-operative effort. The beginnings were local, but with the development of the great war need arose for a national expression of organized contracting. It was accomplished by the creation of the Associated General Contractors of America, today an active and powerful organization working closely with business, engineering and other units of the industry.

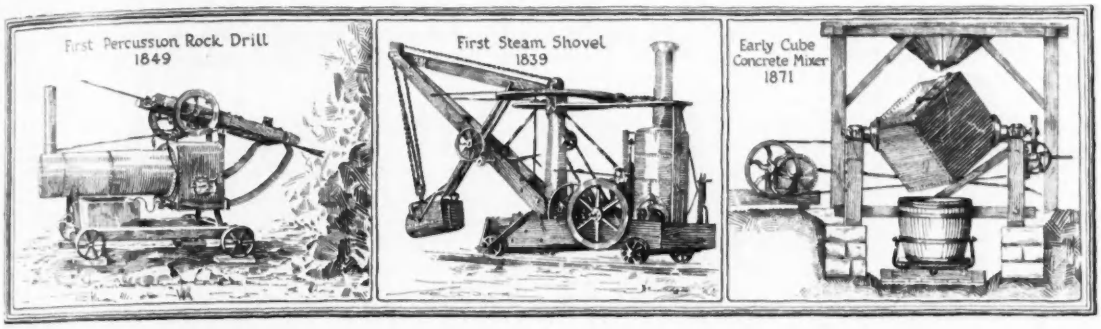
THE PRODUCT of the construction industry during the last half-century is visible to us in our homes, our cities, with their multitudinous structures both above and below ground, our transportation system, our vast economic and industrial plants, our bridges, canals, harbor facilities, irrigation and reclamation projects, hydro- and steam-electric power plants and artistic and monumental structures, all of which are the permanent as distinguished from the expendable wealth of America.

They are the tangible expression of our civilization, as they have always been the important measure of the civilization of every age and nation. The development of these facilities is the great work of the future, into which the savings of our people will find their safest investment so that it is plain that the construction industry occupies a position of possibly first importance. Contracting in various forms is the procedure nearly universally used in construction work and the contractor is the executive, financial and practical agent as the engineer and architect are the technical agents, in association with the banker, the manufacturer of materials and equipment, and the dealer, entrusted with this great responsibility.

The engineer and the architect have for many years been organized, but their organizations are open to the objection of being exclusive and their code of ethics is extended only to the members of their own profession. The contractors' organization is of very recent date and is far from complete, and while these separate organizations are necessary and proper, the co-ordination of all of the factors that enter into construction is as important as the co-ordination of the separate units of a trunk line railroad. The lack of this co-ordination is in part the cause of the present high peak of construction cost. Construction is still the balance wheel of activity, and our immediate greatest interest is to steady its revolution.



Association, co-operation and co-ordination are the stabilizing agents which contractors are just beginning to learn to use and with very excellent results.



Construction Equipment

A Major Factor in Engineering Progress

TO THE development and use of mechanical equipment and improved materials more than to any other factor during the last half century construction owes its growth into a $6,000,000,000 industry. This huge sum represents the value of last year's building and general construction contracts—a program that would have overwhelmed the resources of contractors fifty years ago, when hand-labor methods, supplemented by a limited use of crude mechanical plant, were the constructor's mainstay.

Nearly thirty years ago George S. Morison, in his presidential address before the American Society of Civil Engineers, first outlined his now famous thesis—afterward fully developed in his "The New Epoch"—the thesis of the new phase in the development of civilization wrought by the manufacture of power. But even then we were only at the beginning of the era of the application of power to the uses of construction, an application which has had in its way as revolutionary an effect on the uses of natural resources as have the more spectacular applications to the manufacturing crafts and to industry which were in Morison's mind. The construction industries were among the last to use power—indeed even today those operations conducted in the open resort much more to hand power than those under cover—but when the increased efficiency from power-driven machinery was at last appreciated, the development was rapid and revolutionary. Materials costs and labor rates have gone steadily up but the unit of production has as steadily increased so that, as William Mulholland points out on another page of this issue, "the cost of completed work remains about the same, mainly due to a great improvement in mechanical means of doing work."

This is the great contribution of the machinery builder to the progress of the past half-century. For the American contractor of today the equipment manufacturer has provided an efficient machine at a reasonable price for almost every one of the scores of operations formerly done by hand. In no other country in the world is the range of selection so wide and the design and materials so perfected.

It was not until this country entered upon its great era of transcontinental railroad construction, beginning in the seventies, that any real incentive was offered to inventive genius in the construction equipment field. Up to this time machines for particular purposes had been built for individuals. There was no machine-building industry in the modern sense of the word; manufacture had not even approached a production basis; no stocks were on hand and all orders were specially filled. When the large-scale projects then planned began to take form, however, an opportunity appeared for the continuing and widening use of machines in construction. The seed was sown for a great industry and inventors and manufacturers both set about the task of supplying the needs of engineers and contractors for mechanical equipment during this early period of construction activity in the United States.

Throughout these fifty years the improvement has been steady. The machines have become sturdier, they have become more adaptable to varying conditions and they have become more standardized. Without these improved machines all of the marvelous development of the past fifty years—which the pages of this issue celebrate—would never have been possible. This is the measure of what the engineer—and the world he serves—owes the designers and builders of construction machinery and the makers of structural materials.

IT IS not the function of this article to present a detailed review of the origin and history of the various tools which form a part of the modern contractor's equipment. The field is so large that justice could not be done to the subject in a single issue or in several issues of this journal. In preparation for its Fiftieth Anniversary Number, however, *Engineering News-Record* has amassed a great deal of data of historic interest relating to the representative types of machinery, which will be embodied in a special series of articles to begin next week.

Schoolmen vs. Practicians—Looking Backward Fifty Years

By Robert Fletcher

Director-Emeritus, Thayer School of Civil Engineering, Dartmouth College

THOSE WHO can look back half a century recall the years when practicing engineers in America looked askance at engineering schools and their graduates. In 1874 Thomas C. Clarke read a paper before the American Society of Civil Engineers on "The Education of Civil Engineers." No other paper or discussion on that subject appeared in the "Transactions" of that society until 1904. But, two years after the Clarke paper Alexander L. Holley, then famous as the great organizer and promoter of the bessemer steel industry in America, read his notable paper on "The Inadequate Union of Engineering Science and Art," before the American Institute of Mining Engineers. This led to a joint discussion at the Centennial Exposition in Philadelphia (1876), between the American Society of Civil Engineers and the American Institute of Mining Engineers. At this time the engineering schools were charged with putting too much emphasis on abstract principles not closely related to the objects, phenomena and conditions of practice. The spheres of the schoolmen, investigators, and men of engineering affairs were too wide apart and their labors not correlated. The young graduate was said to be nearly useless, and the so-called "practicians" demanded a change to result in a training which would make him more immediately dependable.

Those speakers who had their experience in combining practical or handicraft work with a more or less extensive school program, systematically pursued for three or four years, seemed to receive the most approval. In those days advocates of shop work in the schools were not quite agreed as to the relative merits of the Russian system, which operated on materials for *instruction* only, regardless of any subsequent utility, and the system which made *"construction* vitalize and guide all instruction." The expounder of the latter system, head of the (then) Worcester Free Institute, explained how the shop was operated on a commercial basis, so that everything made must satisfy a rigid standard of fitness as part of a machine or other construction of marketable quality. Those who advocated training on works as wholly antecedent to the schools were reminded that the merely practical man had always been handicapped by lack of knowledge in emergencies; and of the dictum of Robert Stephenson, about engineering, that "We found it a craft, we have left it a profession."

Holley had asserted that technical education in works should precede technical education in the schools. In the final summing up the consensus of opinion was against him. The view prevailed that education which results in real engineers, as against artisans or specialists, must have a broad basis in knowledge of essential underlying principles and a considerable range of so-called cultural studies. Since then the pendulum has had an ample swing but it seems to be coming back to its position of nearly fifty years ago.

At that time the American engineering schools of recognized standing could be counted almost on the fingers of two hands, and nearly all were on endowed foundations. Then the American Society of Civil Engineers recognized mere professors in engineering schools as eligible to membership only in the "Associate" grade. This situation was only temporary. About eighteen years later they were admitted to the privileges of corporate membership.

During that period a common criticism of the schools by the "practical" men was, "Too much mathematics." The great masters of mathematical exposition like Navier, d'Aubisson, Bresse, Rankine, etc., set a fashion of teaching (by text-books in which there was superabundant use of the calculus) which was said to be too stereotyped and impractical. Methods which wrought such marvelous results in celestial mechanics and thermodynamics were forced upon students, who lacked training to profit by them. School facilities being inadequate, and laboratories almost unknown, the results of mathematical research were embodied in formulas on the blackboard, while the professor performed elementary operations on the other side of the table, and the students simply "observed" and "took notes." The extreme statement of one honored practician and author of a famous engineer's pocketbook was that some master minds "exhibiting a profundity of knowledge beyond the reach of ordinary men" had contrived to "bury the most simple facts under heaps of mathematical rubbish."

SOON after that long remembered discussion the schools began to assert themselves. They made the value and necessity of mathematical training too evident to be disputed. This appeared particularly in the rapid development of the theory of thermodynamics and of electricity and magnetism through experiment and mathematical analysis, and the unnumbered applications in industry and nearly all the activities of daily life. Probably the entire history of civilization presents nothing more astonishing than this immediately effective and pervading influence of pure science upon practical affairs and the welfare of nations. Within two decades the schools brought forth textbooks which at once became standard and indispensable even to the practicians: —treatises on surveying, roads and railroads, applied mechanics, analysis of trusses for bridges and roofs, on

materials of construction, etc. The schoolmen gave to the practicians the graphic statics, the slide rule and planimeter. Engineering students were personally conducted on tours to inspect shops and works under construction.

The subsequent quarter of a century witnessed a phenomenal multiplication of colleges and schools of different grades wherein, to a varying extent, engineering was taught. Many of these were connected with state universities or other institutions supported wholly or partly by state appropriations. Whereas before 1874, the schools had practically no laboratories for testing materials, within a few years a large proportion of the schools were well supplied with testing machines, appliances for hydraulic experiments and facilities for instruction and investigation along many other lines. Practicians became educators, either as lecturers or as heads of departments in some schools. Some schoolmen became practicians as designers and consulting engineers when they found opportunity. Needless to say this interrelation has been extended and intensified ever since.

The great demand which led to and maintained this expansion was world-wide—due to colonization, rapid extension of commercial interests and the need for works which only the knowledge and skill of the engineers could produce. As to America it was said, "Railroads, bridges, water works, sewerage works and mining and metallurgical plants were demanded over the face of the continent. Hundreds were crowding into the service with inadequate preparation. Chainmen and axemen speedily became transitmen and 'engineers.' Such 'practical' men were more ready to criticise the schools than admit their own deficiencies."

CONSIDERING the diversity of location, organization, aims, limitation of resources and the changed and changing professional outlook of more than one hundred technical schools in forty-eight states, there can be no finality of conclusion. Passing in review the various activities of many schools we find considerable experimentation, disagreement and uncertainty resulting from differences and changes in point of view and environment. Mistakes of specialization have been demonstrated—whether by beginning too early in the course or overdoing in variety and extent. Efficiency of teaching has suffered from lack of adequate facilities for handling large classes. Shortcuts and lowering of standards have resulted in low-grade men, as was inevitable.

As to specialization two opinions are informing: "The school for the specialist should come last. Many of our most distinguished specialists had little or no aid from colleges except in a broad, fundamental training. Let the engineering college develop the man in that which is essential to his future activities; but let us beware lest we anticipate too much for one who is yet a student, whose future should not be dictated by overdoing along lines too rigidly and narrowly prescribed."

One comment on the discussions (in 1921) was: "Both the scope and range of subjects covered are so far-reaching and so varied that one wonders whether there is any point of stability in the whole field. The variety of suggestion and range of subjects from the most fundamental and important to the inconsequential and commonplace seem to indicate that no two individuals, either teachers or practicing engineers, have any substantial thing in common." This came three years after the report of the joint committee on engineering education. Dr. C. R. Mann, under the auspices of the Carnegie Foundation, had worked four years from 1914-1918 in a thorough investigation of the engineering schools. The general discussion of the report by the society at large and members of the committee, showed that there was no general agreement upon all of its recommendations.

THE higher education does not stand alone. A college of agriculture and mechanic arts, under some form or name, is found in every state. The federal Commissioner of Education, as far back as 1902, reported 50 such schools for white students and 16 for colored students. They usually give a four years' course approximating college grade. They are commonly supported both by the state and by allotments from the federal government. Some have been given the dignity of a university and some are directly connected with the state university. Of these it has been said, "They are near to the people, are comparatively inexpensive and are largely attended. They have more than justified their cost, though most of them are not altogether fulfilling the purposes contemplated in the original enactments."

Nor can correspondence schools be ignored. Organized with a commercial aim chiefly, a few have been prominent for more than thirty years. According to the Commissioner of Education (1902) some have had enrollment of more than 200,000 students at one time. Official comment was, "It will be seen that the greater part of the receipts for tuition go for securing and retaining students, rather than for instructing them."

The remarkable development of engineering schools and the multiplication of their facilities during the past twenty years are matters of common knowledge. The period has been marked by some munificent new endowments in sums of hundreds of thousands or millions of dollars, and increments of millions to the funds of some of the older and more famous schools and colleges. As to quality, the verdict of the committee of the society on the higher engineering colleges, given as far back as 1900, is no less true today, to wit: " . . . they are now, and have been for many years, graduating young men generally as well equipped in both theory and practice as can be found anywhere in the world." The conspicuous records of many hundreds of graduates since that time vindicate this judgment.

There is now a disposition to come back—after years of experimentation, uncertainty and disappointment—to the judgment given at the conclusion of the discussion in 1876. It appears also that there are a few of the older schoolmen who have adhered consistently to that judgment without uncertainty or hesitation, and have during the entire period advocated and maintained a five-year course. The weight of opinion is opposed to any policy of speeding up which prevents thorough mastery of the fundamentals of engineering science and practice, and a needful extent of broad culture. The four-year course is now declared to be inadequate for preparation to meet the exacting demands of the profession today; and some think that even the five-year course may prove to be too short to enable the graduate to grapple effectively with greater, more diverse responsibilities in the near future.

Foundation Development During Fifty Years

By Daniel E. Moran
Consulting Engineer, New York

THE HALF-CENTURY from 1875 to 1924 has been a period full of inventions, a golden age of discovery and development in most branches of science and engineering. One important field of engineering, that of foundation design, is a partial exception. Foundations for buildings have been improved, particularly the spread footing; but in deep foundation work there has been practically no advance, and the methods used today, in general, were old in 1874. Indeed not a few were time-honored when this country established its independence.

The art of constructing foundations has developed with the requirements of civilization. Its beginnings date back to the first attempt at a fixed and stable structure. The wealth and energy of the earliest civilizations, and notably of the medieval ages, were largely expended in constructing great buildings and bridges, and the master builders studied and knew foundations. The fundamental problem was understood and a general solution was found at an early date, leaving less room for improvement in foundation work than in newer branches of engineering.

Builders at all times, when confronted with unsatisfactory sites, have had to choose between a spread footing, that is, a base or footing expanded laterally at a convenient level so as to impose a low unit load on unstable material, and a deep foundation, consisting of piles or piers penetrating the unstable material to reach a more stable material on which a much higher unit load may be imposed. In making their choice they have, perforce, been guided by the conditions at the site and the limitations imposed by the materials, tools and methods available at the time. Prior to 1874 the high price of steel and iron limited designers to the use of cast iron, masonry and timber.

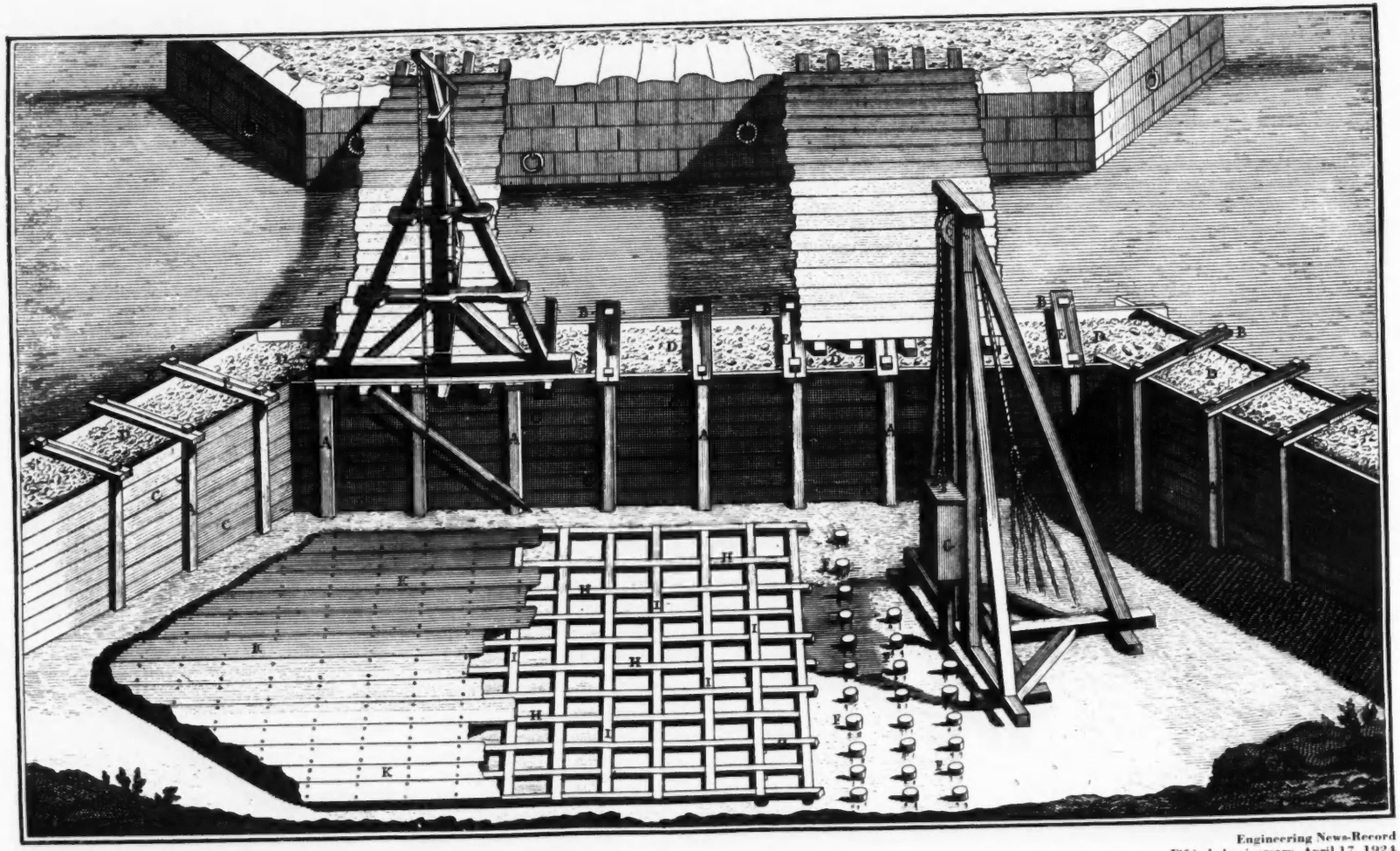
In the case of buildings, where the new demands of modern life and new materials have improved the superstructure, there was also room for improvement in foundations. Lack of steel limited the spread of footings to that obtained by the use of masonry batirs or offsets in the base of the structure, or by the use of inverted masonry arches—means which were generally sufficient for the buildings of the period but not economically adequate for larger and heavier constructions with highly concentrated loads. In the case of deep and subaqueous foundations for bridges there was no need of steel, and the necessity for bridges from the very earliest days had produced processes, inventions and highly developed methods of construction to such a degree that by the time the present era began the prior art was rich in precedents, leaving apparently little room for improvement of basic character; but as power became available and modern machinery was developed, the range of the foundation-builders' art expanded greatly in each of its applications.

It is interesting to consider how fully and ingeniously our forefathers had applied their limited resources to foundation work. Wood piles and sheet piles, cribs and cofferdams were used since the times of the ancients, and at the end of the 18th century the principal element lacking was steam power. Piledriving leads were arranged for plumb or batter piles; the drop hammer was fitted with nippers which opened automatically at the top of the stroke; a gang of men pulling at ten or twelve cat-tails leading to the hoisting rope or climbing the rungs of a circular tread mill, or horses revolving a capstan, served to lift the hammer.

Elaborate cribs and cofferdams made watertight with puddle and sheetpiling as shown in the old plate reproduced herewith were in use and were the subject of engineering publications. Illustrations in Col. Belidor's "Architecture Hydraulique," published in 1753, gave to George Semple, an Irish builder, the information he needed and the confidence to use the cofferdam method in the rebuilding of the piers of Essex Bridge in Dublin, although Labeley, then building Westminster Bridge in London, had discouraged him on account of the difficulty in dewatering a deep cofferdam. It was this lack of efficient pumps that limited the use of cofferdams. Perronet at Neuilly in 1768 used an undershot waterwheel driven by the current of the River Seine outside an earth cofferdam to rotate a water-lifting wheel inside of the cofferdam, which dewatered the excavation; but this expedient was not everywhere applicable, and the hand pump was the principal tool for the purpose.

A FRENCH engineer before our Revolutionary War had used a watertight floating caisson with detachable sides, in which the masonry for a pier was laid until its increasing draft landed the pier on piles previously driven and cut to a proper level by an underwater saw, precisely the method often used since and only recently employed by an eminent engineer for a bridge pier in New England.

The illustration on page 672, taken from Diderot's Encyclopedia of Art and Science, published about 1770, illustrates an open caisson ready for launching, as known in those days. Other illustrators of the same time show the machines used in cutting off piles below water and dredging machines of the type called "Hollandaise," actuated by men on treadmills, but in principle and in many details curiously like dipper dredges and steam



A Bridge Pier Foundation In 1770

Fac-simile reproduction from Diderot's Encyclopedia of Arts and Sciences

shovels of the present day. The lack of efficient dredges of the clamshell and orangepeel type delayed the development of the dredging or well sinking method, although where water did not interfere sinking a well curb and its superimposed circular wall was a common method used by well-sinkers and miners in Europe and has long been employed effectively for sinking bridge piers in India.

The pneumatic caisson method using compressed air is comparatively a recent invention, although the diving bell had been frequently employed before 1800. Lord Cochrane in 1830, toward the close of his romantic career, patented the use of compressed air in constructing piers and tunnels, and his description of an air lock and the way in which compressed air functions is as clear as any twentieth century technical paper. In 1839 we have Triger in France, in 1851 Sir William Cubitt in England, in 1852 L. J. Fleming in Georgia sinking iron cylinders by the pneumatic caisson method. The commencement of the Civil War found Gen. William Sooy Smith sinking similar piers at Savannah and sent him hurrying north to rejoin his West Point classmates. After the war, at Waugaschance, with the early American engineer's genius for adapting the material at hand to the desired purpose, he built the first timber caisson, using timber for working chamber and roof. This was a small affair, to serve as the foundation for a lighthouse; it was a pigmy compared with the giants soon to be built by Eads for his great arch bridge at St. Louis and by Roebling for the Brooklyn Bridge.

IMMEDIATELY prior to 1874, there was in this country unprecedented activity in bridge building. Roebling had begun the East River bridge, and in the West, as a result of keen rivalry between the railroads for the possession of undeveloped prairie kingdoms, bridges were being thrown across the Mississippi and Missouri Rivers.

After the early work of constructing the Rock Island, Clinton, Quincy and Dubuque bridges over the Mississippi River, the five years 1870 to 1874 saw the completion of nine bridges over the Mississippi and six over the Missouri. Eads' Bridge at St. Louis easily outranked all others, but there was considerable difficulty in constructing the piers in the Missouri River and practically every method in use today was resorted to. Following is a list giving the date of completion and location of each bridge and the name of its engineer:

1870	Kansas City, Mo.	O. Chanute
1871	St. Charles, Mo.	Gen. Charles Shaler Smith
1872	Omaha, Neb.	Gen. William Sooy Smith
1872	Leavenworth, Kan.	Gen. W. W. Wright
1873	St. Joseph, Mo.	Eddy D. Mason
1874	Boonville, Mo.	Gen. William Sooy Smith

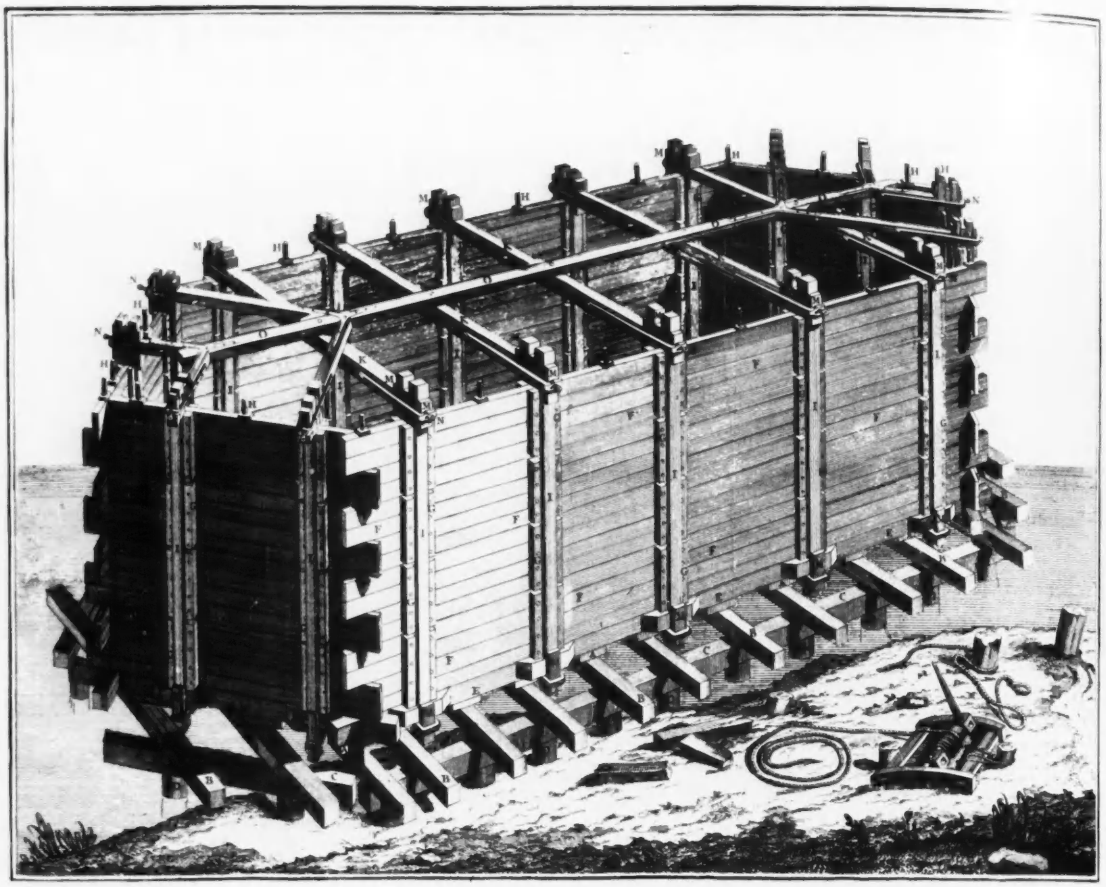
Practically every method in use today was employed in the construction of the foundations for these bridges.

The early development of methods used in deep foundation work thus briefly outlined left little room for radical changes. The art has advanced chiefly in detail and due to freer use of steel and concrete and of improved machinery for executing work. Concrete piles have largely replaced wooden piles; steel interlocking sheeting has a wider range of usefulness than timber sheeting. Reinforced concrete, withstanding tension more than granite masonry or timber, is now an indispensable construction material. Improvements in derricks, steam hammers, pumps, dredges, steam shovels, the invention and introduction of concrete mixers, compressed air drills, hammers and boring tools, and the gas torch, have facilitated excavation and foundation work. The introduction of orangepeel and clamshell dredges enabled American engineers to sink the piers of the Hawkesbury bridge in New South Wales by the dredging method. This work, a brilliant achievement in its day, embodied the same principles used last year in sinking the cylinders and cribs for the support of the anchorages for the interstate bridge between Philadelphia and Camden. Two of the reinforced-concrete cribs, part of the Camden anchorage, each 40 x 140 ft. in plan, were sunk by this method through the silt, sand and gravel of the river bank to rock, 110 feet below high-water level in the Delaware River.

IN PNEUMATIC caisson work there has been little change other than the increasing use of reinforced concrete. The writer's invention of an excavating lock which permits an ordinary bucket to pass in and out of compressed air without the necessity of detaching the bucket from the hoisting rope has proved useful. Improved air compressors, the use of the telephone and the electric light in the working chamber, better understanding of the physiological effects of compressed air, and use of the hospital lock have facilitated the work of sinking and have greatly decreased the danger to the workmen.

The pneumatic caissons used by Modjeski last year for the river piers of the Philadelphia-Camden bridge were fitted with horizontal locks and galleries in the body of the pier, affording safer and more convenient access to the working chamber, but otherwise differed little from the caissons sunk by Eads before 1874. In depth of sinking and size of caisson, there is little to choose between the older and the most recent piers. Roebling's working chamber was of wood, 102 x 170 ft.; Eads' was of boiler plate, 60 x 82 ft.; Modjeski's of steel and reinforced concrete, 70 x 128 ft.; and all were sunk to a depth of over 75 ft. Fifty years have seen but little change in the major elements employed in this type of foundation work.

MATTERS are reversed when we consider foundations used for buildings, and naturally so, because the buildings of 1874 were very different from those of today and their foundation requirements were easily satisfied. The buildings were lower, and the walls and piers, being of masonry, could bring no high unit loads, certainly no great concentration of load, down to the footings. Offsets in the base of the wall supplemented by footings projecting only slightly beyond the wall sufficed to reduce the unit load sufficiently for ordinary soils, and where the conditions were bad the same footing was placed on wooden piles. There were some failures, and the cellars in many cases were largely occupied by masonry and brickwork, but in general the designs met the requirements. Inverted arches were used occasionally, but in general a simple footing course made of concrete, or of large flat stones, rested on the soil



AN EIGHTEENTH-CENTURY FLOATING CAISSON WITH REMOVABLE SIDES

directly or on timber piles cut off below low water. A grillage of plank was sometimes placed on the piles and served as a platform on which to construct the footing course. Typical examples of the early type still standing are the Sub-Treasury in New York City, the Capitol at Washington, and the Capitol at Albany, not to mention the older commercial buildings still surviving from the early part of the last century.

With the advent of the skeleton steel frame for buildings, the increased height and weight of buildings and the concentration of weight in single columns rendered the old type masonry footing inadequate, and designers were forced to design the footing as a girder and to use steel as resisting bending better than masonry. Following the use of railroad iron in a footing in the boiler room of the Montauk Building in Chicago came the use of rolled beams in grillages, one or more layers in height, and combinations of grillages and built-up girders. More recently, reinforced concrete is frequently used in place of structural steel grillages, permitting a wide range in design, the size of footings varying from that necessary to support a single column to a composite footing or mat covering the entire area of the building site and distributing load concentrations quite dependably over large bearing areas.

Not only has the spread footing been highly developed, but deep foundation methods have been employed for building foundations. In 1893 Kimball & Thompson, architects for the Manhattan Life Building in New York, confronted with the dangers of a site underlain with quicksand, appealed to Charles Sooysmith, son of Gen. William Sooy Smith, to construct the first pneumatic caisson foundation for a building. Adhering in part to past methods, he built the piers (which were sunk to rock with the aid of compressed air) of brick, as being more reliable than concrete. The piers for the nearby American Surety Building, sunk the following year by the same method, were also of brick, and the writer, who was resident engineer, well remembers having to forcibly take levels and plumb-bobs from the brick masons as being untrustworthy guides in carrying up a true line when the pier was shifting and twisting on its way down.

Modern buildings demand increased space in the basement and cellars for machinery and other purposes. This has led to increasing the number of basements below grade and providing a continuous exterior wall to serve as foundation for the exterior columns and as a retaining wall or cofferdam resisting the pressure of soil (or soil and water) on the outside of the wall.

Constructing a Deep Foundation for a Modern Building (Barclay-Vesey Building, New York Telephone Co.)

One of the first examples of the use of a cofferdam foundation was the Mutual Life Building in New York (1900), where Alfred Noble designed a wall of caissons forming a continuous cofferdam to permit the cellar excavation going below water level. The gaps between exterior caissons were closed by stock ramming with clay. T. Kennard Thompson was in charge of this work.

The extent to which space below the curb can be utilized is perhaps best shown in the Federal Reserve Building, recently constructed in New York, where 2,912,000 cu. ft. of space (182,000 sq. ft. of floor area) was provided below curb level for machinery, vaults for securities, storage of various kinds and other general uses. The deepest floor is 80 ft. below the high curb on Nassau St., and the deepest pier is founded 118 ft. below the same level.

Since 1892 details of construction in pneumatic work have rapidly improved. O'Rourke developed a "timber stave caisson" which acted as an exterior form for a concrete pier and used a removable roof. The Foundation Co. introduced all-concrete working chambers, removable interior shafting, removable exterior forms and many other improvements, and the late T. B. Bryson successfully used a new method of safely closing large gaps between caissons.

Along other lines there have been noteworthy developments. In Chicago, a method of excavating deep wells in clay known as the Chicago method has been very successful, and may be considered an improvement on the old miners' method of using vertical lagging boards. In piledriving, timber piles are being replaced by concrete piles of several types. The reinforced-concrete pile cast and seasoned before driving represents the direct substitution of concrete for wood. Another type uses a steel shell and driving mandrel, the shell being left in the ground to act as a form in which the pile is cast. A third type uses a pipe, closed at the bottom by a loosely fitting cast-iron point; when driven into the ground, the pipe is filled with concrete and then withdrawn, leaving the concrete pile and the point in the ground. A fourth type uses an open pipe which is driven in the ground. After the material inside the pipe is excavated by a jet of compressed air, the space is filled with concrete, and both pipe and concrete filling are left in the ground. The last method is frequently used in underpinning buildings, the driving being done with a hydraulic jack. Other variations are in use.

The evident advantage of the concrete pile is that when properly made it is permanent whether wet or dry, avoiding the danger of decay to which wooden piles are subject if the water level is below the cutoff level, a danger difficult to provide against in these days when subterranean constructions change the water level.

In conclusion it may at least be claimed that foundation design has kept pace with the demands of the superstructure and has utilized new materials and facilities as they became available. If the progress has not been spectacular, it has been sufficient; and we may count with confidence on the engineers of tomorrow to develop the foundation art farther as rapidly as may be required by the new problems which will surely result from progress in other fields.

Progress in the Art of Tunneling

By J. Vipond Davies
Consulting Engineer, New York

IN REVIEWING the development in the art of tunnel construction during the past half century, corresponding to the life history of *Engineering News-Record,* one's mind naturally reverts to the great antiquity of the art as disclosed by the extensive and marvelous archeological discoveries of recent years. Have these fifty years not after all been too short a time to evidence great advance in this branch of engineering practice? Drinker writing in 1878 the preface of the first edition of his monumental work commences, "Tunneling at the present day is a profession in itself," thus indicating that considerable advance had been made in the art at that time. While the tremendous advance in science and the mechanical arts gives reason to anticipate a great expansion also in this branch of engineering, the question arises what particular conditions called for changes in the tunneling art. The answer is not hard to find.

The direct purpose for most tunnel construction is to provide means for transportation. The earliest tunnels built in Europe were links in canal systems, and the first tunnel built in the United States, in 1818, was part of the Schuylkill Canal in Pennsylvania, measuring about 22 ft. high by 15 ft. wide. Compare this with the Rove tunnel, recently completed in France for similar canal navigation purposes, measuring over 72 ft. in internal width.

The development of the modern steam railroad requiring limitation of grade and curvature, shorter mileage and access to the great centers of population, which are commonly isolated by natural barriers, gave a great impetus to the need for tunnels. Add to this the other needs of concentrated population, such as interurban transportation, sanitation and water supply, and at the same time the greatest advance the world has ever known in the knowledge of science and the mechanical arts, and there are combined the needs and the means for satisfying those necessities.

Longest railway tunnel in America

ENTRANCE TO ROGERS PASS TUNNEL

WITHIN the areas of great cities the conditions became most acute, so that with the growth of population came the urgent necessity for elimination of grade crossings of thoroughfares and provision of other arteries of traffic to secure safety with regular and rapid service, on a plane other than the surface of streets and properties in order to release to their proper and normal uses the streets themselves. In that way have the grade elimination and rapid-transit developments evolved themselves.

The question and the answer are purely *economic.* In railroad service, the period corresponds almost exactly with the development, initiated by A. M. Wellington, of economics as a branch of railway engineering.

What was the situation of the art fifty years ago? At that time the Mt. Cenis, the first of the many tunnels through the Alps, had just been completed and opened for traffic (1871). In this country, the Nesquehoning and many other less important tunnels were completed, the Musconetcong and Hoosac tunnels were in process of construction, but not yet ready for traffic. Exactly half a century ago, the inaugural address of President Harrison of the Institution of Civil Engineers of London states in reviewing the then situation:

"Hoosac Tunnel is nearly approaching completion. The St. Gothard Tunnel is in active progress. These works are of no ordinary magnitude."

"The use of concrete is still comparatively in its infancy but the great rise in the price of cement has retarded its adoption."

He goes on to note that Chicago had obtained a pure water supply by a tunnel under Lake Michigan.

The English Channel tunnel had been proposed as far back as 1857 but only a little initial work had been done prior to the period we have under study. Various patents were taken out between 1856 and 1875 for tunneling machines intending to excavate a full cross-section of tunnel at one operation without use of explosives. In fact, so far back as 1857 such a machine was built with the idea of using it in the Hoosac tunnel; but it was not until about the commencement of this period that the Brunton machine was actually installed on the French end and the Beaumont machine on the English end of the Channel tunnel, both of which did successful work in the easily splintered chalk formation. Little or nothing, however, has been accomplished with this system or the project since that time.

The Mt. Cenis tunnel was started with hand drilling and gunpowder was used as an explosive until about 1860. Thereafter it took about two years to install satisfactorily and test in practical work the use of compressed air and rock drills which from 1862 to 1870 were used exclusively.

So, while as far back as 1847 the effect of nitric acid

on carbohydrates to produce unstable explosive compounds had been known, it was not until 1863 that nitroglycerin was made, and 1867, dynamite. Both the air-driven rock drills and modern high explosives, therefore, came into practical and successful use just about the commencement of our half century.

The St. Gothard Tunnel was then under construction and introduced the first mechanical blowers for ventilation of the works.

In this country the Hoosac tunnel was actually commenced in 1862 with hand drilling and gunpowder. Between 1864 and 1867 Burleigh rock drills were introduced with compressed air obtained by water-power turbines. In 1865 nitroglycerin was imported from Europe and later was made at the works and continued throughout the work as the principal explosive, although in 1874 dynamite was used in part with nitroglycerin, thus anticipating the recent practice of using high-power gelatin for the "cut" in conjunction with a lower grade to back it up. In 1866 electric firing of explosives was introduced although such a system of group firing by electricity was patented in 1830. Similarly in the Nesquehoning tunnel (1870-1871) rock drills with American steel and compressed air were used, while with the soft rock encountered it was found that black gunpowder gave better service than nitroglycerin and was fired with electric spark. In the Musconetcong tunnel (1871-1875) Ingersoll drills were used with dynamite as an explosive.

In building the earlier Alpine tunnels considerable difficulty was experienced in the proper ventilation of those very long tunnels, as well as due to the interference of transportation of heading excavation with the work of enlargement. Consequently, when in 1893, the Simplon tunnel was designed and commenced, the plan included the driving of a pioneer tunnel parallel with and at a short distance from the location of the main tunnel, connected by cross passages at intervals. The entire work from 1893 to 1905 was carried out in that method as fully described and illustrated in *Engineering News*. In the more recent building of Rogers Pass Tunnel (C. P. R.) 1913-1916, this method was adopted to expedite the progress of the work. In that case, however, there was driven in the main tunnel a heading placed in the center of the cross-section, from which ring blasting of the full section was carried out by radial drilling.

In the field both of rock tunneling and soft-ground tunneling, necessitating timber support, it may be said at once that there has been little advance in the half century, except in the development of mechanical appliances, materials of construction, improved power service and electric lighting, experience of labor and other details.

The development of successful muck loading machines, electric power for lighting and power purposes and the great improvement of the mechanical design of rock drills, Leyner water circulation for high speed drilling, high pressure blower ventilation for properly ventilating the face, greatly improved design of air compressors, and the use of gelatin explosives giving the greatest explosive effects with the minimum of deleterious gas, and the recent development of non-freezing gelatin powders are the lines in which this branch of tunneling has advanced in the half century.

In the timbering of heavy tunnels, it must be admitted that little, if any, advance has been made except such as corresponds with the materials of construction available and obtainable. In the United States we have developed a system of timbering along the lines of what may be termed the transverse method, as differing from the longitudinal systems used in England and elsewhere in Europe. This method is better adapted to our materials, leaves an entirely open full-sized cross-section, so that the timber put in for construction can remain permanently as a timber lining and we have educated our labor to a thorough understanding of its uses and application. This, however, has been a gradual

Penstock Tunnel of the Niagara Falls Power Co.

STEEL CENTERING IN A LARGE ROCK TUNNEL

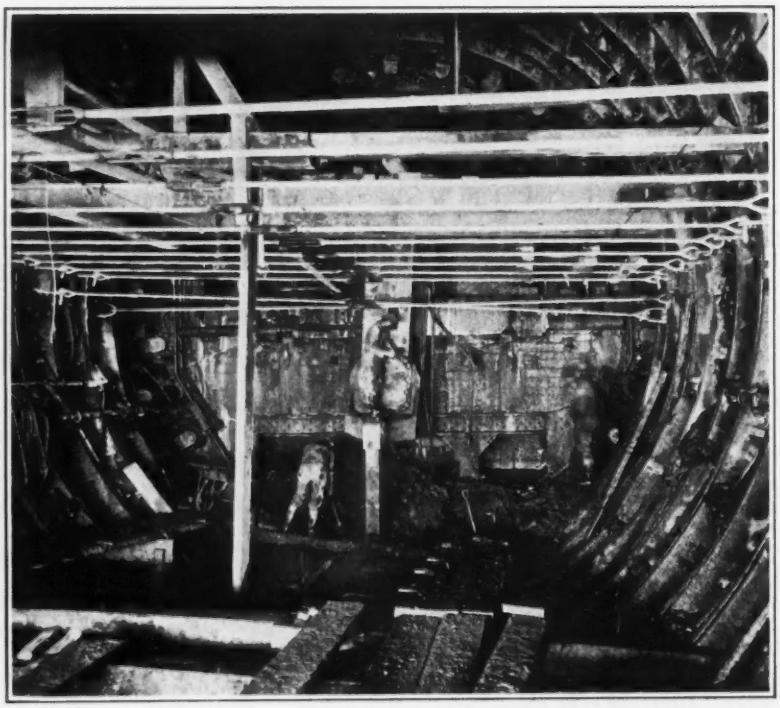
evolution and is not attributable to this specific period of time, as this system was used as early as 1854.

As native round timber has become further remote from tunnel works requiring either temporary or permanent lining, and as sawn dimension lumber has become more and more expensive and less and less sound and durable, there has grown in recent years an increasing use of fabricated steel shapes, accurately milled in the joints and spliced with fitted fish-plates for the sets to support the arch loads of heavy ground tunnels, thereby giving greatly added strength and safety. These steel sets are usually embedded permanently in, and tend to reinforce, the concrete arch lining.

As regards the permanent lining, the greatest change is from the use of stone and brickwork to that of a plastic material, concrete, which, for the arch construction particularly, is deposited with the minimum of labor behind portable and traveling steel forms, by shooting through pipes at high velocity under pneumatic pressure. The importance of the American method of timbering is emphasized with this development in concrete lining.

As a work coming almost entirely within this class,

heavy ground timbered tunneling, it is interesting to note that half a century ago the Metropolitan Underground Ry. in London had completed and was operating, with very great difficulty in ventilation, the first section of its property, which was the first provision of rapid transit in a great city. It was not, however, until 1884 that the complete Inner Circle of that railway was finished, before which date openings had to be made in all the earlier constructed work to provide ventilation. Prior to this period, it had been recommended to design the Metropolitan Ry. with single-track twin tunnels instead of with double-track single arches, so as to provide better for ventilation by the operating movements of trains. In fact the year 1874 appears to represent the date when the first serious scientific attempt (developed from the study of operation in the Mt. Cenis tunnel) was made to solve the question of ventilation of long tunnels.



Construction now in progress; largest shield tunnel built

AT SHIELD OF HUDSON RIVER VEHICULAR TUNNEL

The greatest change has, however, come in connection with the totally different treatment of the methods of construction of tunnels, which in older days were next door to impracticable of accomplishment by mining and timbering owing to water. The unstable soil difficulties of these cases have been eliminated by the use of pneumatic pressure and a shield, providing methods which, while based on earlier theories, are in all practical and essential ways attributable to the half century beginning about 1874.

The adoption of compressed air and a shield has made tunnel construction practicable in any soil and under any conditions, provided the necessary working pressure is not in excess of 50 lb. above normal.

While the basic patents of Brunel for a shield and Cochrane for use of pneumatic pressure were then quite old, we nevertheless find ourselves, a half century ago, in the position that Barlow and Greathead had recently completed the little Tower Subway in London (7 ft. 1¾ in. in external diameter) using a simple form of shield advanced with screwjacks, with cast-iron segmental lining and lime grout pumped behind the lining, but no air pressure.

Simultaneously under Broadway in New York, A. E. Beach had just completed a short length of tunnel (9 ft. 4 in. in outside diameter) proposed to be the initial work for a scheme of pneumatic tube transportation which he was promoting, and in which he used no air pressure but did use a shield fitted with hydraulic jacks and in part used cast iron and in part brickwork for lining. The original Thames tunnel of Brunel (1843) designed to be a highway, utilized a shield with screwjacks and brickwork lining but did not utilize air pressure.

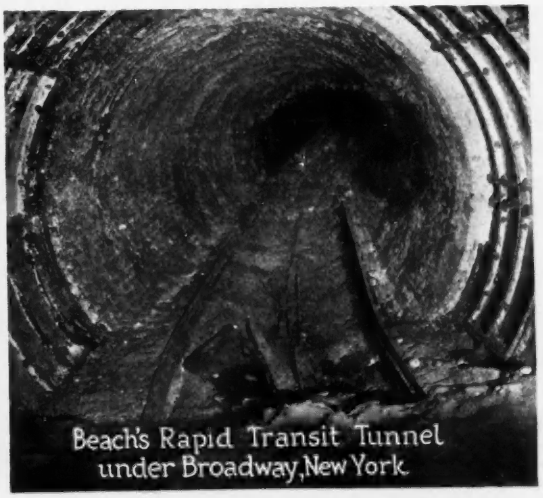
Consequently, notwithstanding that the fundamental ideas already existed, the complete history of development of the now well-known shield method of subaqueous tunneling falls within the half century period; for Haskin came to New York and promoted the Hudson River tunnel and took out a patent for a method of tunneling under air pressure in 1874 and built the first portion of that work in 1879, lining the same with brickwork. This work now forms part of the Hudson and Manhattan R. R. system. In the same year, Monsieur Hersent drove a footway tunnel in Antwerp measuring 4 ft. by 5 ft. in cross-section, using air pressure and iron lining but no shield.

The economic need for subaqueous tunnel construction, other than such rock tunnels as the Severn or the Mersey in England, or those of a later date, the Astoria Gas or Storm King aqueduct in New York, started in 1886 with the construction of the London and Southwark tunnels (10 ft. 6 in. in diameter), now a part of the City & South London Ry. In 1888 the installation of a shield with use of iron lining (19 ft. 5¼ in. in exterior diameter) and air pressure was substituted in the Hudson River tunnel at New York for the previous method of lining with brickwork without a shield. In the same year, Joseph Hobson made a similar installation for the 21-ft. tunnel under the St. Clair River (Grand Trunk Ry.), the soil in this case being far better than that of the Hudson River. In dimensions these two projects far surpassed anything that had gone before.

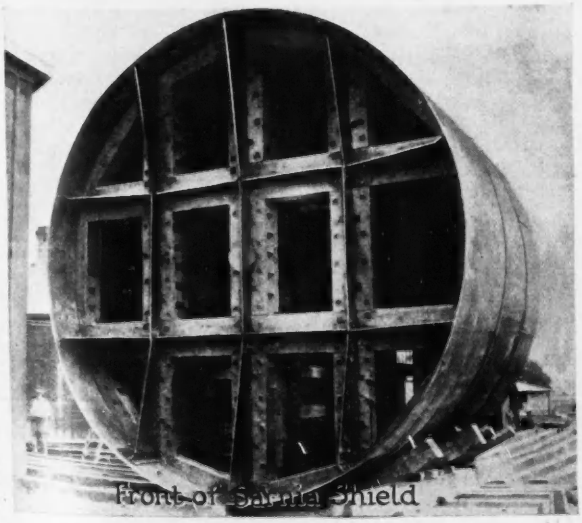
Steel Segment Timbering, Liberty Tunnel

Portal of Niagara Penstock Tunnel

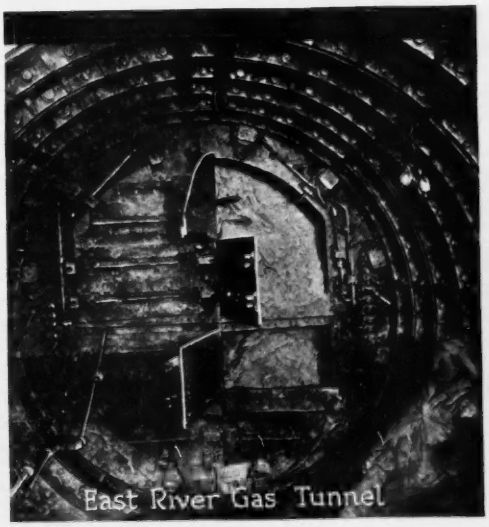
Haskin's Brick Tunnel under Hudson River
H.&M. Shield Entering



Beach's Rapid Transit Tunnel
under Broadway, New York



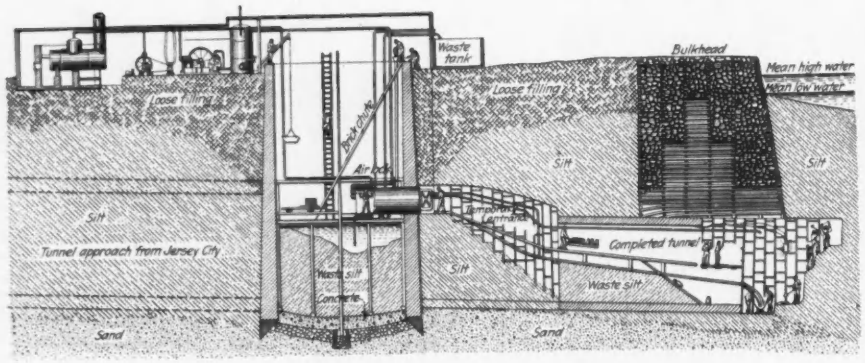
Front of Sarnia Shield



East River Gas Tunnel

In 1866 Morton had patented the use of hydraulic jacks (which appear to have been first used by Beach) and his patent includes internal bolting of flanges of plate lining and an inflated packing between tail of shield and lining, which last has never proved to be successful. The invention of a machine erector for erecting plate lining for tunnels was included in a project by Greathead for a subway at Woolwich, never built.

In the St. Clair and Hudson tunnels all the essential elements of modern practice in subaqueous tunnel work were brought together. In neither of these works was grouting done, as the soils were not such as to render it desirable, but extensive high-pressure grouting was done under air pressure, with a shield, iron lining, lead and iron borings for calking of joints, in the Ravenswood tunnel of the East River Gas Co. in New York in 1892-1893. In this work the working pressure used probably exceeded any other employed in this class of work (47 to 52 lb. maximum) although it was approximately equaled in the more recent building of the nearby 60th St. rapid transit tunnels.



HASKIN STARTING TUNNEL UNDER HUDSON WITHOUT SHIELD

The type of lining used for shield-driven tunnels in the first instance by Beach in New York and Barlow in London, and since then adopted as standard practice, consists of internally flanged and bolt-connected segmental plates of gray cast iron. For local use in plates subjected to heavy stress, the Hudson and Manhattan R.R., the Pennsylvania R.R., and more recently the Hudson Vehicular tunnel have used cast-steel lining of the same patterns to obtain greater strength. Looking to the future possibility of increased tunnel dimensions and consequent strains, it may become necessary to use cast steel more extensively as a normal material of construction, or possibly to develop a fabricated steel primary lining giving great strength with considerable economy in first cost.

For the successful prosecution of any tunnel work under conditions which are peculiarly onerous it is a foregone conclusion that the builders must have plant, tools and equipment which have been thoroughly tested and proved. In fact, what is necessary is to have all plant as near foolproof as possible.

Roof shields to deal with inadequate cover in heavy soil were first used in Baltimore but later more successfully in Paris, in the Boston subway and in New York City subways. Usually in these cases side headings are driven by timbering methods for the foundations and side walls, and thereon the roof shield is advanced for construction of the complete arch. This adaptation of the shield principle falls entirely within the half century period.

Another type of tunnel for subaqueous use, whose complete history is written in this half century and for which a brilliant future may be anticipated in cases where its important advantages outweigh its local disadvantages, is that of the trench or caisson type, itself of many effective designs, as typified by the Detroit River tunnel; the Métropolitain, in Paris; and the Harlem River tunnels of the New York subway system.

IN CONSIDERING the subject of tunneling, it is usually contemplated that that category includes only those structures which are built by underground methods from within. At the same time there is a large and important class of these structures which, in the result attained, are without doubt tunnels, although they have been constructed entirely from without. Within this class falls the innumerable subways used by steam railroads, and more recently developed to an enormous extent for the systems of city transit. In the first instance, without doubt, these types originated in deeply depressed open-cut railroads, either with or without slope walls, bridged overhead at road crossings. Later the retaining walls were made of gravity section to withstand the pressures for the full depth. Then when the value of surface properties and street requirements made it desirable to restore the surface, these open-cut ways were roofed over continuously by arch construction or by girders and masonry and then back-filled over the top. A large proportion of the Metropolitan Underground Ry. in London was built by this cut-and-cover construction. The method came with the growth of the railroads, but it is entirely within this half century period that the present methods of steel and concrete construction such as have been used in New York City have developed.

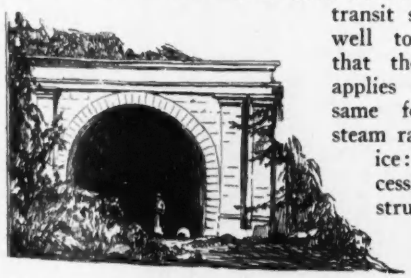
RAPID TRANSIT VIA TUNNEL

The first definite change came in the building of the first Rapid Transit Subway (Contract No. 1 executed in the year 1900). In preparation of the plans it was early recognized that the subsurface improvement within street lines required the economizing of every inch of space in width and head room, both in the construction period and in the permanent occupation. To give the greatest internal dimensions with the minimum external occupation, a composite type of lining consisting of a fabricated steel framework, such as was then being utilized for lofty buildings, using concrete for the jack arches, was designed. The use of tight sheathing for retaining the cut, driven as excavation is taken out, braced across the open cut, gave the greatest economy in space occupied during building operations. The first New York subway was built literally in open cut, to the hopeless obstruction of traffic in the streets. In the more recent work of this character the timbering supporting the sheathing has been utilized by laying thereon a solid substantial deck of heavy planking extended over the greater part of the width of streets, beneath which excavation may proceed and at the same time preserve so far as practicable the surface use to the public.

The necessity for handling rapidly and efficiently the daily transportation of the population of the great cities by underground methods has been the cause for the greatest impetus in development in the art of tunneling.

New York in the magnitude of its enterprises, both on account of its density of population and the riding habit of its people, has surpassed the world. In the combined works of the states, the city and all the public utility companies, there is represented an aggregate value of tunnel construction exceeding in present value a billion dollars, which includes construction of every type and for every conceivable purpose.

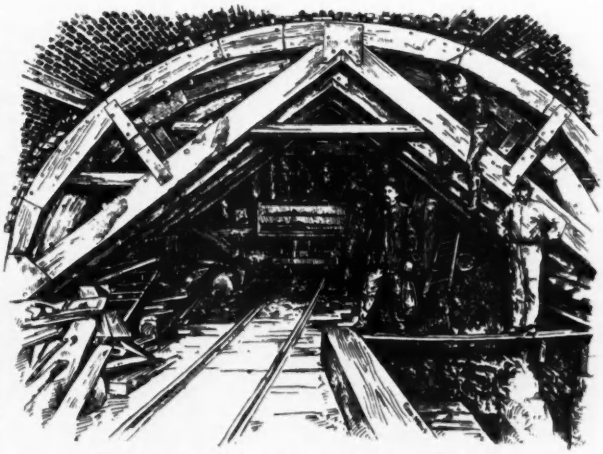
While the Rotherhithe tunnel, an extension of the London highway system, has an exterior diameter (30 ft.) which is 6 in. greater than the normal exterior diameter of the Hudson River Vehicular tunnels (29 ft. 6 in.), now under construction (page 676) nevertheless the magnitude of the undertaking and the depth and character of the soil and water channel are so much more severe as to make the latter a far greater undertaking. As a matter of fact, for ventilating purposes a considerable section of the Hudson River Vehicular tunnel on the New Jersey side has been increased to 30 ft. 4 in. external diameter. Similarly the aqueduct tunnel, tunnels for gas transportation and sewer disposal, beside those for main line railroad service into and within the city area, far surpass any such work attempted previously and elsewhere. In the field of what we know as rapid-transit service it is well to remember that the condition applies with the same force as in steam railroad service: that the necessities for construction coincide with the ability to operate safely and efficiently, due to the successful development of electric motive power for operation of the service.



Portal of Old Allegheny Tunnel

Had Haskin's Hudson River tunnel been completed as planned originally when commenced in 1879, as a through connection for the steam railroads terminating in Jersey City to a union station at Washington Square, it could most certainly never have been operated. Even so late as 1907 the operation of the New York Central and New Haven railroads into the old Grand Central Terminal through the Fourth Avenue tunnel had become a public nuisance, and before the underground railroad lines in London were finally electrified about the same date, they were in a similar condition. The introduction, therefore, of electric power is directly responsible for the immense growth and development of tunnel construction within the half century period.

These changes have come coincidently with the great expansion in the various classes of tunnel work, so that with better working conditions, we have, in the United States, developed a trained and experienced class of American labor, having methods of its own, capable of meeting any possible conditions of work, and not now surpassed in efficiency or knowledge of the art by any other labor in the world.



Heading of Tunnel in Mixed Ground

It appears clear, therefore, that the period immediately preceding the advent of *Engineering News* was fertile in developing the science and the fundamental ideas underlying the modern development of tunnel construction, but that on the other hand the half century now passing has seen the art develop to its high state of fruition, to meet the new necessities which have arisen. Increased experience with constantly greater success in construction, manifestly multiplies the possibility for more and more tunnels to meet the ever growing needs for all classes of use and service.

Portal of Sarnia Tunnel

Growth of Steel Frame Buildings

Origin and Some Problems Of the Skyscraper

By H. J. Burt
Consulting Engineer, Chicago

HALF a century encompasses practically the entire development of metal framework in buildings. In fact 1874 antedates by a dozen years the first skeleton construction and is only six years later than the introduction of the elevator, which made possible the general use of buildings higher than four stories.

The rapid increase in the size of cities, bringing with it congestion of people and of business activity, was demanding greater and greater floor space in small areas. Vertical expansion was necessary. Introduction of the hoist or elevator in 1868 made it practicable. Improvements in elevators have kept pace with building developments so that vertical transportation is satisfactorily provided in the highest structures that have been built.

As buildings become higher and space more valuable the limitations imposed by old types of construction with thick masonry walls came to be burdensome and there was need of a material of greater strength for building supports. Also the increasing congestion necessitated better fire protection, hence combustible materials must be eliminated as much as possible.

METHODIST TEMPLE, CHICAGO

At the beginning of this period cast-iron and wrought-iron columns and beams were available. These materials became of practical importance in building construction about 1850. The manufacture of steel rails had made a good beginning in 1874, and steel in the form of beams and columns became available a decade later, the first steel beams being rolled in 1885. Brick arches supported on iron beams had been used as early as 1840, and terra cotta arches were introduced in 1871, so that important steps in fireproof construction had already been taken. The great fire in Chicago had emphasized the importance of better fire protection. The highest buildings at that time probably were not more than eight or ten stories.

In the ten years following 1874, a gradual increase in the height of buildings with masonry supporting walls occurred, until twelve-story buildings were not uncommon and at least one sixteen-story building had been built. However, interior masonry walls had been replaced by iron columns and girders to save space. The fireproofing of steelwork was given a great deal of attention. Terra cotta floor arches almost entirely replaced brick and other types. Terra cotta also became generally used for fireproofing the iron columns. The typical up-to-date business building, then, consisted of masonry bearing walls for the exterior and generally for some interior walls, cast-iron or wrought-iron interior columns, wrought-iron girders and joists, terra cotta floor arches serving as the floor plate and as fire protection for the steel beams and girders, terra cotta encasement of columns, and cast-iron lintels over openings in exterior walls.

It was but a normal growth from the type of building just described to the complete steel-frame building, in which the masonry walls were eliminated as supporting elements of the structure and used only as an envelope. The elimination of the masonry bearing wall being the distinctive feature of skeleton construction, the old type of store front may be considered as the prototype, for in that construction the masonry wall of the first story was omitted and the upper wall supported on beams at the second floor level.

Three architectural concerns of Chicago are credited with the advance which constituted the transition from masonry supports to iron and steel supports. These are Burnham & Root, W. L. B. Jenney, and Holabird & Roche.

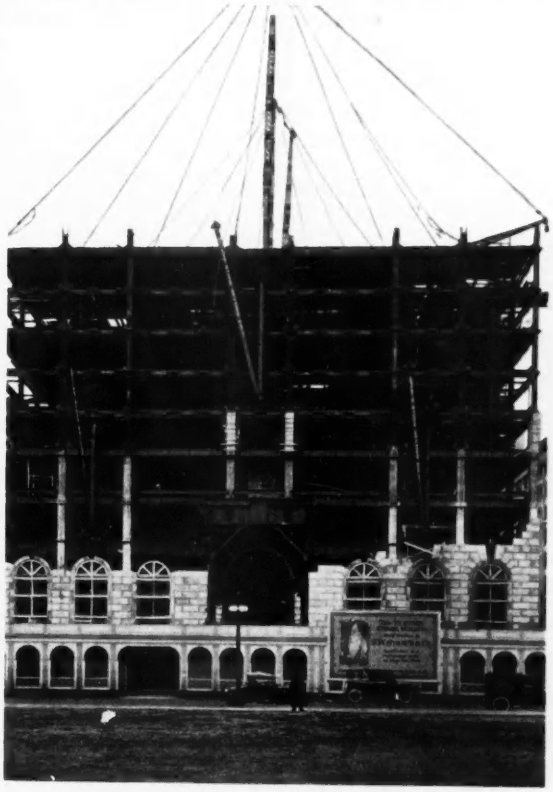
Burnham & Root designed the Western Union Building, at Clarke, Jackson and LaSalle Sts., Chicago, in which is a small court back of the elevators whose wall is a double wall of tile supported on iron beams. This, like the store fronts, was skeleton construction so far as this small piece of wall was concerned, but no attempt was made to apply the principle in general to the building, which has heavy masonry bearing walls.

A near approach to the skeleton form of construction was the Home Insurance Building at LaSalle and Adams Sts., Chicago, built in 1884 from plans of W. L. B. Jenney. It was originally built ten stories in height, later increased to twelve. In order to secure large windows the masonry piers were reduced in size by relieving them of all floor loads. To accomplish this, cast-iron columns were built into the piers and to these columns the iron floor beams were directly connected. The comparatively thin spandrel walls between piers were supported on cast-iron lintels bearing on but not connected

to the cast-iron columns. Thus the masonry piers were required to support only their own weight and possibly the weight of the spandrel walls (depending on the actual execution of the work). The structure lacked being a complete metal framework in that (1) the spandrel beams or lintels were not directly connected to the columns, merely resting on brackets on the columns, the details of construction being such that it would not have been possible to have erected the upper part of the masonry envelope in advance of the lower part, and (2) the masonry piers of the building had a load bearing function.

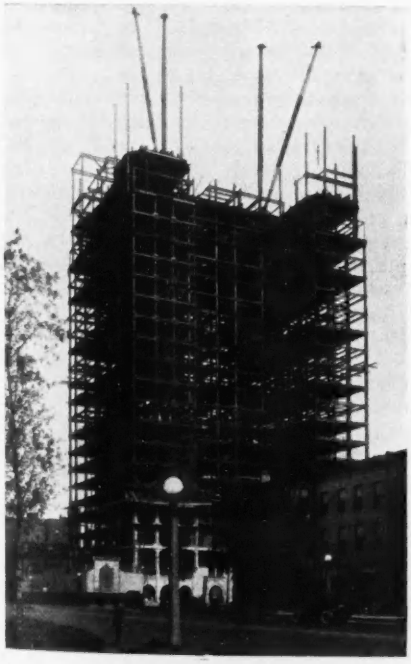
The next important step was the construction of the Tacoma Building in 1886 and 1887, from designs made by Holabird & Roche, which had true skeleton construction for the street-wall framing and which established fully the principle of eliminating masonry supports and using the masonry simply as a curtain wall or envelope for the building. The framing of these walls consisted of cast-iron columns with cast-iron spandrel beams at each floor level supporting the enclosing wall of the story above.

The first plans for this building, made in 1886, were for a 12-story structure 25 x 125 ft., having a street on one side and one end. Bearing walls and piers for a building of such height and such narrow width seriously curtailed the floor space, which led to the design of curtain-wall construction for all four walls of the building. The architects give credit for the idea to Sam Loring, who, as a manufacturer of terra cotta, had some time previously submitted to the architects a design for supporting a terra cotta wall on iron framework. The demands of the problem in hand brought to mind this suggestion and it was adopted Work was about to proceed on the building when the property involved was consolidated with the adjoining piece, making the ground 80 x 125 ft. The plans for the enlarged property were drawn with skeleton framework on the two street frontages and masonry walls on the other two sides, and the building was so constructed. Although not a complete metal frame it introduced successfully skeleton wall construction, and this type came into general use very rapidly thereafter.



Typical heavy steelwork in lower stories of a high building; girder over entrance carries two main columns

STRAUS BUILDING, CHICAGO



FRAME OF MODERN APARTMENT HOUSE

Within the three or four years following the construction of the Tacoma Building at least half a dozen buildings were constructed in Chicago eliminating entirely masonry bearing walls and establishing what for the time was known as the Chicago type of construction. In 1890 the Masonic Temple was constructed at State and Randolph Sts. in Chicago to a height of twenty stories. This bold piece of work demonstrated fully the possibilities of the skeleton type, and its use spread to New York and other cities. The Masonic Temple reached the height of practically 300 ft. from base of columns to top of roof, which made it the highest building, though not the highest tower, then in existence.

The skeleton type of construction has now been in use for a little more than 25 years. In that period it has met the ever-increasing requirements of height and of special architectural conditions which would have been

impossible of attainment with masonry construction. There has been no change from the fundamental principle established in the construction of the Tacoma Building, but there has been great advance made in the design of the steel, particularly in meeting special requirements.

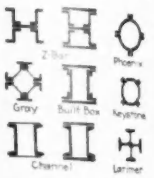
IN MANY of the early buildings in which iron was used as a construction material the motive was protection from fire by the elimination of the combustible floor construction. Iron and steel were long considered fireproof materials, but soon the necessity of protecting them from the burning contents of buildings came to be appreciated.

The earliest form of fire protection used for floor construction consisted of brick arches springing from the bottom flanges of the beams, leveled off with mortar or concrete; no cover-ing was provided for the bottom of the beams. Somewhat better protection was afforded by the addition of a plastered ceiling beneath the beams. Corrugated iron arches have been placed between the beams, there to serve as a form for concrete filling above. These systems of arches between floor beams were objectionable on account of both lack of effectiveness and excessive weight. To meet this condition the terra cotta floor arch was devised and first used in construction about 1871. The demand for fireproof construction of greater efficiency was augmented by the Chicago fire, which accounts for the rapid development of fireproofing during the seventies. The terra cotta arch provided a flat ceiling surface for plaster, protection for the underside of the beams, and a flat top surface for receiving the floor.

One of the earliest skeleton structures

VENETIAN BUILDING, CHICAGO

As columns came into more general use, tiles proved to be more suitable than brick for their protection as well as for protection of the beams. By 1880 the use of fireproof floors and fireproof columns had become well established for the best building construction, so that the introduction of the steel skeleton building called for no radical change in fireproofing methods. Nevertheless fireproofing methods improved parallel with the steel construction. About 1900 concrete began to displace tile as a fireproofing material, and is now the most used material for this purpose, though not perfect; it is desirable that a material be developed which is lighter and has less conductivity and which at the same time will provide the necessary strength for floor construction.



SOME TYPES OF COLUMN SECTION

During the earlier years of the use of the steel skeleton for buildings there was much discussion as to its durability. Rusting was feared. Steel frames of buildings have been in use long enough to establish their durability and to develop the danger points.

In a building wrecked in 1914 in Chicago, about twenty years after it was constructed, the floor joists and girders had tile fireproofing, and an effort had been made to have a continuous covering of mortar on the steel; the paint was practically intact. The columns, encased with tile with vacant spaces along the metal, showed some rust along these air spaces. At one column, due to a leaking soil pipe, the corrosion was serious, the weight of rust indicating a loss of about 1/16 in. of metal. The foundation contained unpainted grillage beams encased in Portland cement concrete. When removed they showed no deterioration whatever. In another building, where there had been a restaurant kitchen for a number of years, examination disclosed that water percolated through to the beams and girders. The corrosion was very serious, the webs of beams and plate girders being perforated in a number of places. Incidental to some shoring operations a number of column bases were exposed in a 16-story building. The columns were encased in hollow tile fireproofing. Considerable rust was found on the steel, enough to indicate the need of much better protection in situations where moisture from the ground can get through to the metal. Concrete encasement was substituted for the tile.

It seems well established that the structural steel in buildings, when properly protected with paint or concrete, is fully as durable as the other parts of the building; an indefinite period of time. But if it is not fully protected serious damage may occur. Those responsible for the maintenance of the early steel-frame buildings should examine them for evidence of deterioration at the most vulnerable points, such as basement columns, toilet room floors, pent houses, and parapet walls.

WIND BRACING was considered when the first design of the Tacoma Building was prepared. This set of plans was destroyed but it is believed that no provision (other than curtain walls and partitions) was made to resist wind pressure. The design was submitted to the late Prof. J. B. Johnson of Washington University, St. Louis, who made recommendations regarding wind bracing. The building as constructed has no special details to resist wind pressure; the rear walls and two masonry cross walls furnish this resistance.

In the absence of masonry bearing walls wind bracing is an essential part of the design of a high building. The simplest type is triangular bracing in a vertical plane, and the easiest form of construction, used in some of the

earlier buildings throughout, is the use of diagonal tension members in connection with the columns and girders acting as compression members. This form of bracing, while cheap and effective, necessitates enclosure in permanent partitions or walls. The demand for convertible space early led to the adoption of portal bracing, with solid web plates and arched openings. This railroad type of portal has been modified in detail but not in principle. Bracketed connections are now used to attach the girders to columns, so forming a modified type of portal bracing.

Wind-bracing brackets inside the building are objectionable in appearance and expensive to conceal. This led to locating the wind bracing in the exterior walls as far as practicable, which can be accomplished readily if the building is nearly square, while in a long narrow building resort must sometimes be had to intermediate lines of transverse bracing.

The computation of wind stresses is the most uncertain factor in the design of a steel frame. The analysis of a single framed bent is quite definite, but when the bents are multiplied both vertically and horizontally with variable spans and story heights it is quite certain that the analysis of the single bent does not hold true. Arbitrary assumptions must be made as a basis for calculations. The wind pressure assumed varies from 15 to 30 lb. per square foot, as defined by various city ordinances or as dictated by the judgment of the designer; 20 lb. perhaps is the most common value. The assumptions now being used give structures which have proven satisfactory. It is customary to assume that the stresses are transmitted by the framework alone as if there were no masonry walls, partitions or floor slabs. To the extent that these elements offer resistance, the assumption is excessive. It is almost impossible to evaluate them, so their effect is disregarded.

In a few buildings horizontal as well as vertical wind bracing has been installed. It sometimes occurs that the vertical planes of bracing offset, so that a considerable amount of shear must be transmitted from one plane to another and horizontal bracing is needed.

Steel being an elastic material deflects under stress, with the result that noticeable horizontal movements occur in some of the high towers. These movements may not overstress the steel, but may ultimately damage the masonry walls and partitions. If too pronounced the movement becomes objectionable to tenants. Experience may develop some information as to the means of controlling the sway of these structures. Heavier bracing and greater ratio of width to height are needed.

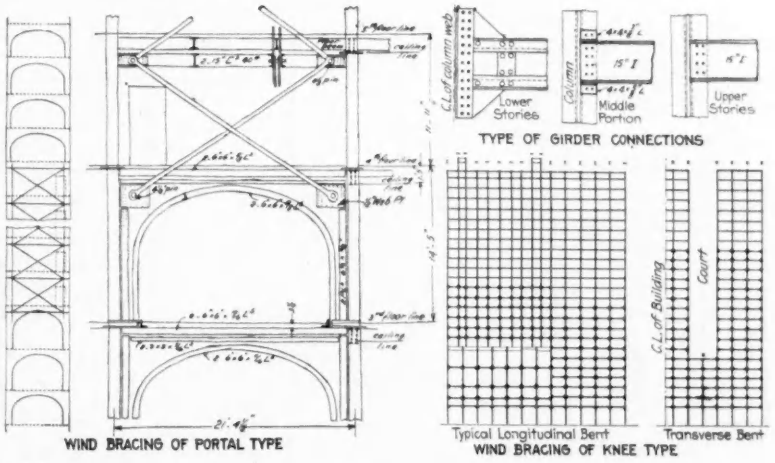
AS HAS been noted, the first skeleton wall was built with cast-iron columns. Cast iron ceased to be used for important buildings about 1890. Wrought-iron columns continued in use until about 1895, by which time they were displaced by steel.

Tubes, the strongest shape, have not been used extensively for columns on account of the difficulty of making connections and the expense of making the tubes. The section for building columns most nearly approaching the steel tube was the Phoenix column, made up of four or more rolled segments of a circle with a flange along each edge, riveted together to form a hollow cylinder with projecting ribs. This section was used extensively in the '70s and '80s. The Z-bar column was in use during practically the same period as the Phoenix column, having been patented in Germany in 1862. Other types of columns which have come and gone are the Larimer, the Keystone octagonal, and the Gray. The channel column is still considered a practicable section; it has a large radius of gyration and offers fair opportunity for connections. Connections to the channel webs must be riveted on before the column is assembled.

The H-shaped column is the most popular at the present time on account of the simplicity of the shop work. This advantage has been sufficient to offset some lack of economy in section. The rolled H-section is a comparatively recent development in this country.

The erection of the structural steel frame of a building is a spectacular affair. A truck load of beams or columns is picked up by the derrick and lifted on to the building with as much ease as if it were a bundle of sticks. Each column and beam is swung into place with accuracy and directness. Red-hot rivets are thrown and caught with as much skill as the baseball. The clatter of the pneumatic riveter is the song of the industry. The whole process contrasts strongly with that used on the early wall-bearing type of building, where all pieces were hoisted and set singly with a gin-pole or a hand derrick moved from place to place as each beam or column was set, where the work of the several trades proceeded one story at a time, and where joints were bolted or hand-riveted.

In many construction situations large unobstructed floor areas are required in order to serve the purposes of a building. Where it is necessary to have this large clear space in the lower part of the building and surmount it with many floors above, the problem ceases to be a



WIND BRACING OF OLD COLONY BUILDING AND OF A RECENT STRUCTURE

simple one. Very heavy plate girders and trusses, equaling or exceeding those used in the heaviest railroad bridges, are sometimes required. Restrictions as to height and width of space available, and the like, may tax the ingenuity of the cleverest designers. The New York Stock Exchange and the proposed Stevens Hotel in Chicago contain outstanding examples of large unobstructed floor areas with heavy structures above, but almost any recently constructed bank building or large hotel offers illustration of clear spaces requiring heavy plate girder work.

Mere size and bulk of building does not offer serious difficulty in the design of the frame, even though columns and girders may be unusually large. On the other hand the architectural treatment of the exterior of the building may impose difficult conditions, especially with Gothic architecture. The Chicago Temple Building of the Methodist Church and the Tribune Tower Building in Chicago are buildings of this character. The facades are such that columns cannot be placed in line, and many special details are required to support the exterior walls. Another problem imposed because of special exterior design occurs in the Peoples Gas Building of Chicago, whose lower stories have a row of granite columns apparently supporting the wall above but actually carrying no load; the structural columns are in the rear of the granite columns and the wall is supported on cantilevers projecting out at the tops of the granite columns. Foundation conditions along property lines sometimes require very heavy cantilever construction. Towers, domes, balconies, cornices and similar features present problems difficult to solve. That steel buildings can be beautiful architecturally is evidenced by a great number of structures, perhaps by none better than the Woolworth Building in New York, which has the added distinction of being the highest steel-frame building yet constructed.

Great height and ornate architectural development

WOOLWORTH BUILDING

Steel construction has met with one competitor, reinforced concrete. Reinforced-concrete buildings, now in use about twenty years, have not only demonstrated their value but also fairly well defined the limitations of use of this material. While several buildings have been constructed of reinforced-concrete framework to a height of twenty stories, this material cannot be considered a real competitor of structural steel for buildings of this height. At the present time its practicable limit seems to be about ten stories. It is of course possible that this may be extended, but doubtless it will be conceded by every engineer that concrete cannot displace structural steel. However, it has encroached on the use of structural steel in buildings of smaller size and in the floors of steel-frame buildings, where concrete often eliminates the steel joists.

A WORD as to the outlook. There is no material in sight at the present time that offers any suggestion of displacement of structural steel as the framework for high buildings. It is recognized and has been proven by the construction of the Woolworth Building and others that steel is suitable for buildings much higher than the average of the present day. An upper limit of practicability has not yet been found.

Nevertheless, improvement in structural steel is desirable, chiefly to give greater economy of cost and space. A steel having greater strength would permit the use of smaller sections, which would mean a saving in space. There are now a number of alloys of steel which have the desired properties, but they have not been developed on a commercial basis that makes them available for use in building construction. Nickel steel is the most nearly available of any of them, but is still too expensive. Economy would also be promoted without change of steel quality, by increasing the basic working stress from 16,000 lb. per square inch to 18,000 or more, but this step still lacks the endorsement of any of the engineering societies.

Perhaps the most promising prospect of reducing the cost of steel-frame buildings is by lightening the loads which they must bear. From 50 to 80 per cent of the stress in the columns of the building comes from dead-load; there is room for improvement—improvements are being made—in the construction of floors so as to reduce the dead-load. It is probable that fireproofing materials will be improved in a way that will reduce the weight.

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Half a Century of Road Development

By C. S. Hill

Associate Editor, ENGINEERING NEWS-RECORD

HIGHWAY system development, state and federal financing, centralized administration, traffic management, structural permanence—all that is distinctive of modern public roads—are the creation of a far shorter period than the life of *Engineering News-Record.* In its present import there was no rural road improvement in 1874. With the decline of the toll road, following the advent of railway transportation in 1830, public roads entered their dark age which endured almost sixty years in America. Then came the renaissance. It is this period, since about 1890, which embraces the vital activities of road development in the fifty years since 1874.

Never, of course, was there cessation of highway development. Provisions were regularly made for laying out and caring for roads and road taxes were levied during all the period of highway desuetude from 1830 to 1890. Control of roads was strictly local—township and county supervision—and the manner in which they were built and kept up depended on the intelligence and energy of this supervision and was hampered further by the prevailing custom of paying road taxes in labor. Near towns and on a few routes connecting the larger towns improvements might be high—metal bridges, gravel surfacing, telford and macadam construction—but such instances were uncommon. The prevailing road was a dirt road, seldom truly constructed, only occasionally repaired, often good with favoring soil and drainage and weather, never good all the year and frequently impassable in fall and winter and spring.

In such way highway development continued until 1890. Then, or starting perhaps two or three years before, there came a rebirth of the spirit of roadbuilding which matured into the present enormous construction program—the greatest public works undertaking in the world's history. This growth may be regarded as having three phases: (1) The period of promotion; (2) state-aid development; and (3) federal-aid development. In a measure these periods overlap, but it helps understanding to consider them separately.

It was the bicycle which brought the first impetus to highway improvement and inaugurated the period of promotion. The production in 1885 of the low-wheel model and in 1888 of the pneumatic tire made millions of people bicycle riders in the next ten years. They organized. In 1887 the League of American Wheelmen was created. It became almost immediately an organization to promote road improvement. It published a magazine. Through this publication, by enlisting the interest of public men and through the institution of road meetings, a veritable wave of enthusiasm for road improvement was created out of which grew the next step which was federal legislation. This was first expressed in an act of March 3, 1893, creating, with an appropriation of $10,000, the Office of Public Roads Inquiry.

As its directors conceived it, the function of the new office was to promote improved roads. The propaganda of the League of American Wheelmen had prepared the way. Disciples were easy to enlist. Indeed the people had already begun to band together into "good roads" associations. The federal road officials encouraged this organization activity and joined in the association work. The statement has been made that at one time there were two-score national and over six hundred state and county organizations—all promoting road improvement.

Gradually there was a cessation of the early brass-band methods but promotion continued. Good roads associations in great numbers were active for another ten years and a few are still powerful agents in advancing highway improvement. Other forces came to bear. One was the inauguration of rural mail delivery. The more important influence was the development of motor vehicles. Practical automobiles began to come onto the market shortly after 1893. Ten years later saw the motor truck beginning to be used. In 1904, it has been computed there were 58,000 automobiles in use. In 1914 there were in use, of all types of motor vehicles, 1,700,000. Today the number is some 15,000,000.

ABOUT the first practical evidence of awakened interest in roadbuilding was agitation for state aid to counties and townships. This movement began in Massachusetts and in New Jersey at about the same time in 1887. A New Jersey state-aid law was passed in 1891. In 1893 Massachusetts enacted a similar law and created a commission for its administration. At first the administration of the New Jersey law was put in the hands of the State Board of Agriculture but in 1893 the office of Commissioner of Public Roads was created. It is stated that the first money paid out for state aid in roadbuilding was in New Jersey on Dec. 27, 1892. Before 1900 five other states had adopted state aid. In 1917 every state in the union gave state aid for roadbuilding.

Centralized state administration of highways had its beginning with state-aid legislation, though every state did not create a highway department until federal-aid legislation in 1916 required it. With state-aid, system-development of highways began. Every state now has its system of state roads. Centralized administration and system-development are in 1924 fundamental prin-

ciples of highway improvement. State aid also brought the problem of state highway financing. Previously all expenditure and hence all financing had been local. The new problem assumed enormous proportions and the endeavor to solve it has brought the most notable imposition that the world has known of special taxation for public works—the motor vehicle license tax and the gasoline tax, which in 1923 amounted to $225,000,000.

State aid gave a tremendous impetus to road improvement work. It was not, however, until federal aid was undertaken in 1916 that the real roadbuilding era began. The federal-aid idea was of slow growth. For a dozen years prior to legislation, bills providing for some form of federal aid were introduced in Congress at every session. The final law was a notable one. It gave the nation control over the character of its investment without infringement of state sovereignty. It provided for maintenance of road property. It required centralized state administration. It called for system development. It demanded financial partnership from the state. It was altogether perhaps as sound and constructive public works legislation as any government ever evolved.

With the impetus from federal aid, expenditures for road improvement have increased rapidly. They are now about a billion dollars a year for all purposes. About six-tenths of this expenditure is for local roads and the remainder for roads of the federal-aid and state systems. Comparative expenditures for 1874 are not known. In 1904, however, only twenty years ago, it is reliably estimated that the total expenditure for rural roads was not quite $60,000,000. Financing so enormous an increase has been possible by taxing heavily the motor vehicle user. He pays nearly half of all the costs of road construction and maintenance.

Of roads of all kinds in the United States there are about 2,860,000 miles. Of this total about 220,000 miles are under state jurisdiction; broadly they are the state-system roads. The federal-aid road system, as now laid down, is about 183,000 miles, mostly included in the state system. All but the state and federal-aid system mileage, or some 2,640,000 miles of road are under local-county or township jurisdiction. In 1874 there was none but local jurisdiction of highways.

IT IS reliably estimated that there are some 390,000 miles of highway on which there is some kind of surfacing. Of this surfaced road about 30,000 miles are paved. All but some 13 per cent of American highways are therefore earth roads, probably averaging better but not remarkably better than the earth roads of 1874. Then, however, there were few other than earth roads. All paved roads and largely all surfaced roads have come in fifty years. The significant contrasts between 1874 and 1924 are consequently in surfaced road structure and construction. They are striking.

Waterbound roads of broken stone—telford or macadam or a combination—were the highest type road structures in 1874. They held their supremacy, with a proud record of large mileages constructed, until well after 1900. With fast automoble travel under which it rapidly wore out, waterbound macadam declined in use. Today it is scarcely considered as a road type. In its place have come the bituminous types, brick pavement, concrete pavement and their combinations. All the new types have come into considerable use on rural roads only since 1890.

With high-type road structures, construction methods and equipment have become more complex. Outside of his teams and hand tools, the old macadam roadbuilder required only a roller and sprinkling cart to which were added crusher, screens and bins if he produced his own broken stone. Today either bituminous or concrete roadbuilding calls for heaters, mixers, distributors, motor trucks, rollers, pumps, industrial railways and half a dozen other complex machines calling for high mechanical skill in selection, operation and maintenance. Control of product is an equally cunning task. In brief, the roadbuilder today is a specialist of high skill equipped with complex and special machinery.

HIGHWAY engineering has become equally a specialty. It is not the task of the general practitioner. Indeed as the business of highway building has developed under state and federal aid there is little occasion for the independent practitioner. Practically all engineering of main roads is in the hands of federal, state and county highway department engineers. In 1874 and indeed long afterwards, such engineering of highways as there was in America was by independent practitioners.

Various influences have worked to make highway engineering a specialty. The first perhaps is the concentration of roadbuilding in the hands of governmental units. Second is the enormous increase in speed, weight and volume of traffic. Third is the use of complex materials and particularly of rigid structures for road surfaces. Fourth is the development of the highway as a co-ordinate factor in general transportation economics. Out of this expansion of the functions of highway engineering have grown the requirements for research which has reached remarkable proportions since large construction programs have developed. From the same reason also have come the courses in highway engineering and highway transport in the engineering schools and the multiplication of books on roads and roadbuilding.

Of the developments of half a century none registers a greater change in highway thought than the general extension, with popular support, of the practice of rigid maintenance of roads by trained organizations under the constituted highway authorities. This is all a part of the growth of the concept of highway service. Fifty years ago the highway, of such character as it might be, was provided for the traveler to get such use of as he could. Today the thought is rather to proffer service by snow removal, dust elimination, cutting down construction hindrances, providing guide and caution signs and furnishing good general maintenance. The idea has come that the road is an activating element in transportation service. Road improvement to produce increased traffic had no place in thought in 1874 except in the private business undertaking of toll-road construction. In the roadbuilding of 1874 there was no operating problem; today this is the biggest problem.

In the life of *Engineering News-Record* roadbuilding has developed from a mere pathmaking task of local import to a public works enterprise of interstate and national importance. It stands on the threshold of a further development exceeding in importance and cost all other means of transport.

Sources

Engineering News-Record and its predecessors: All prices in 1879, 1885 and 1886; iron and steel prices from 1894 to 1909; all prices from 1910 to 1924.

Aldrich report of the Senate Finance Committee of 1893: All prices 1874 to 1878; 1880 to 1884; 1887 to 1891.

Bureau of Labor Statistics: All prices in 1892 and 1893; prices of brick, cement and lime for 1894 to 1909; lumber prices for 1898 to 1904.

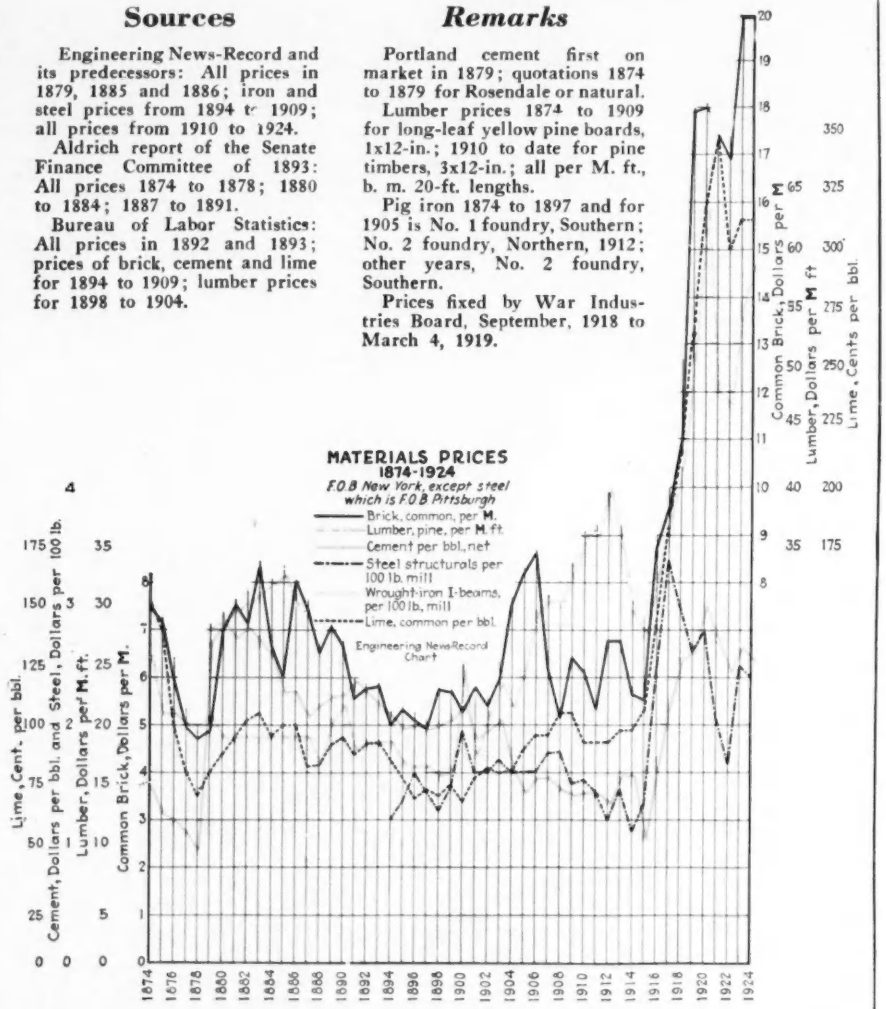
Remarks

Portland cement first on market in 1879; quotations 1874 to 1879 for Rosendale or natural.

Lumber prices 1874 to 1909 for long-leaf yellow pine boards, 1x12-in.; 1910 to date for pine timbers, 3x12-in.; all per M. ft., b. m. 20-ft. lengths.

Pig iron 1874 to 1897 and for 1905 is No. 1 foundry, Southern; No. 2 foundry, Northern, 1912; other years, No. 2 foundry, Southern.

Prices fixed by War Industries Board, September, 1918 to March 4, 1919.


MATERIALS PRICES
1874-1924
F.O.B New York, except steel which is F.O.B Pittsburgh
Brick, common, per M.
Lumber, pine, per M ft.
Cement per bbl, net
Steel structurals per 100 lb. mill
Wrought-iron I-beams, per 100 lb, mill
Lime, common per bbl.
Engineering News-Record Chart
Lime, Cent. per bbl.
Cement, Dollars per bbl. and Steel, Dollars per 100 lb.
Lumber, Dollars per M ft.
Common Brick, Dollars per M.
Common Brick, Dollars per M
Lumber, Dollars per M ft
Lime, Cents per bbl.

Sources

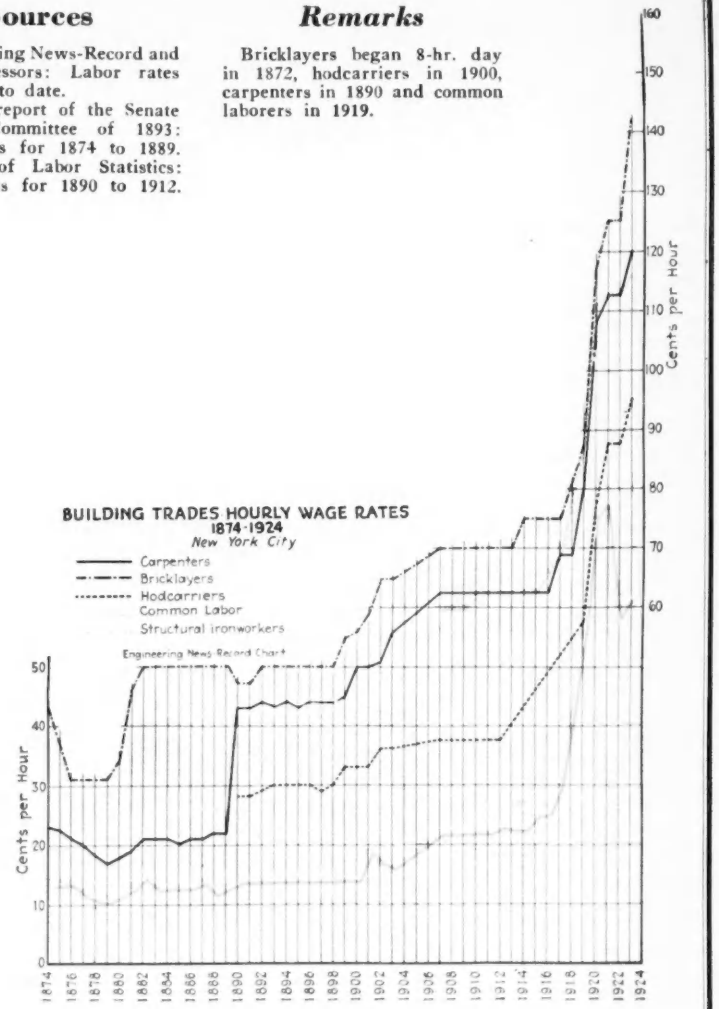
Engineering News-Record and its predecessors: Labor rates from 1913 to date.

Aldrich report of the Senate Finance Committee of 1893: Labor rates for 1874 to 1889.

Bureau of Labor Statistics: Labor rates for 1890 to 1912.

Remarks

Bricklayers began 8-hr. day in 1872, hodcarriers in 1900, carpenters in 1890 and common laborers in 1919.



Engineering News-Record Diagrams of Materials Prices and Labor Rates—1874 to 1924

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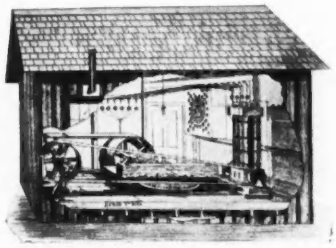


First hydro-electric plant, Appleton, Wis., 1882

Hydro-Electric Power

An Achievement of the Past Half-Century

By J. D. Galloway

Consulting Engineer, San Francisco

IT IS a pleasant custom that has been sanctioned by time occasionally to pause and take stock of what has been accomplished in any given line of endeavor. Such occasions present themselves when one has rounded out some definite period of time and since this journal finds itself at the completion of its fiftieth year, it is fitting that a survey by made of those phases of engineering which form the subject matter of its pages. Time flows on at a uniform rate but the progress of mankind is not regular.

In no portion of the field of human endeavor has there been a greater advance than in engineering. It may be said with truth that modern civilized life would be impossible without engineering development. However, the advance in related fields of endeavor has been equally great—in education, in medicine and in that department upon which all depends—pure science. If emphasis is laid upon engineering in general or upon some definite phase of engineering, it is done with full appreciation of the services of those investigators in pure science who have built the foundations upon which any applied science must rest. To cite one example is sufficient. The discoveries by Volta, Ampere and Faraday, of the laws of electricity were necessary before the modern electric generator became a possibility.

This sketch is limited to the development of hydro-electric engineering during the past half-century. In none of the various phases of engineering has greater progress been made nor have any had a more definite effect upon the material conditions of the people. In fact, the art of hydro-electric engineering is the product of the last fifty years—one may almost say of the last thirty-five years. Hence it is that the inspiration which comes to those dealing with a subject that is new has been experienced by men yet in the prime of life whose fortune it has been to deal with hydro-electric engineering. The writer well remembers the thrill of pleasure when he stood at the receiving end of the first transmission line over one hundred miles long, the Colgate-Oakland line, and witnessed the instruments indicate the turning on of current one hundred and forty-one miles away in the canyon of the Yuba River.

One must now turn, however, and acknowledge the work of the men who came before, the pioneers upon whose invention and study of natural laws the present development is based. The generation, transmission and distribution of hydro-electric energy involve the work of three major divisions of engineering —mechanical, civil and electrical. They blend together in the hydro-electric power plant and the supervising engineer must have a general knowledge of them all. At the same time he must depend upon the specialist in each department for the detailed solution of the problems involved. For these reasons, in selecting a point of departure fifty years ago it is in order to summarize the state of the art at that time in the three divisions of engineering upon which it depends.

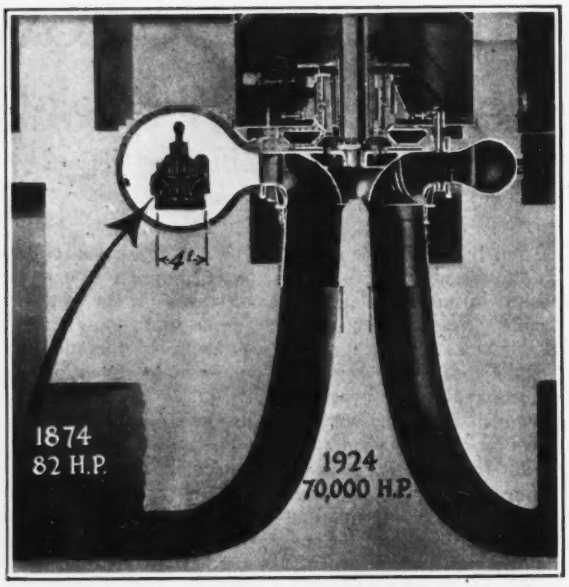
IN 1874 the turbine was a well designed and effective machine. The design originated by the American engineers Howd and Francis, with an inward flow and central discharge of the water, has prevailed over that of the European engineers. The overshot wheel had been discarded in favor of the turbine. Uriah Boyden had designed the spiral approach, and Leffel the modern type of speed gate. The turbines were small, usually of less than 100 hp.; one of 200 hp. capacity had been built which was not successful; all were operated under extremely low heads. The manufacturing cities of New England, Lowell, Manchester, Lawrence and Holyoke, had arisen at the site of falls, just as later cities grew where there are waterfalls, as at St. Paul, Spokane or Oregon City. Along with the development of turbines came the methods of accurately measuring large quantities of water. The testing flume at Holyoke remained until recent years the standard place for determining the efficiency of turbines.

The other prime mover, the impulse wheel, was the

invention of California miners. The principle was clear to Italian, French and English writers. Atkins applied for a patent on the device in 1853. In California the miners used crude wheels to drive their mills in the decade 1850-60. In 1866 a wheel was installed in the Gwin mine, the buckets of which reversed the direction of the jet. The dividing wedge was patented in 1873 and improved by L. A. Pelton in 1878-80. The names of Knight, Coleman, Moore, Pelton and Doble are associated with the early development of the wheels, the use of which became very general in the west, especially in mining.

THE data of the first use of a turbine to drive an electric generator are not at hand. One of the earliest installations in America was the Oregon City plant, built in 1889. The first use of an impulse wheel for this purpose was in 1891 at the Chollar mine in Virginia City, where, under a head of 1,680 ft., six units were installed of 100 hp. Brush dynamos operated by 40-in. impulse wheels.

The California miners had invented the rockfill dam and their hydraulic mining led to the construction of hydraulic filled earth dams. They developed the wooden flume and built ditches along the steep canyons of the rivers. They extended the use of riveted sheet iron pipe and used it in large sizes up to heads of 1,700 ft. and over. There was thus ample precedent for the high head impulse wheel driven unit.



Risdon wheel, 1874, 18 ft. head, 82 hp., 45 sec.-ft.
Niagara wheel, 1924, 213 ft. head, 70,000 hp., 3,300 sec.-ft.

HYDRAULIC TURBINES, 1874-1924

Fifty years ago the electric generator, or dynamo as it was called, was almost unknown. The first station supplying current for arc lighting as a commercial enterprise was built in 1877-78. Small central stations with steam driven dynamos were built in the decade 1880-90 and these formed the nucleus of the great systems of today. In 1886 the transformer was first used in the building of a constant pressure alternating current system.

THE decade of 1890-1900 saw the beginning of hydro-electric development. The first transmission of power to any distance was from the Cerchi-Tivoli steam plant to Rome, 17 miles, built in 1886. The Oregon City-Portland line, already mentioned, the first hydro-electric long distance plant, commenced operation in 1889. The first three-phase plant, the principle of modern transmission, was placed in operation September, 1893, at Redlands, Calif. By the end of the century the design of plants and equipment was upon a firm basis. Generator and transformer design was becoming standard; the oil switch had been invented and insulators were built to stand a pressure of 40,000 volts. The largest generators were the 3,730-kw. machines at Niagara Falls, driven by an improved type of turbines. Impulse wheels were improved by the needle nozzle, first deflecting and later supplied with a bypass.

SINCE the beginning of this century progress has been upon well defined lines, following those of the earlier developments. Among the devices that have come into use are the vertical shaft units on improved bearings, the synchronous bypass, the balanced valve, surge chambers, welded steel pipe, and, on the transmission line, suspension insulators and steel towers.

Progress in size has been rapid. Commencing with short lines operating at pressures of a few thousand volts, the transmission lines are now from 200 to 300 miles in length and operate at pressures up to 220,000 volts. Single generators of 20,000 kw. driven by two impulse wheels are in operation at the Caribou Plant in California. In the West the largest turbine driven units are those at Pit River Plant No. 1, of 35,000 kw. capacity while on the Niagara River a recent installation has a turbine of 70,000 hp. capacity.

The laws of electricity are well understood and design is now along certain and definite lines. In both electric and hydraulic machinery the efficiencies obtained in large units approach close to the maximum possible and little if any advance may be expected in the future. Surges in conduits with the design of protective devices have been made the subject of investigation by Durand and Johnson. The experimental data as to annual load factor have been accumulated to a point where the characteristics of any one system can be determined in advance with reasonable certainty. The functions of reserve steam plants as adjuncts of hydro-electric systems have been worked out. The former isolated plants or systems are rapidly becoming parts of larger systems, giving continuous service and providing energy at a rate that makes it the cheapest and most flexible power known.

The ability to carry energy to great distances by electricity has changed the type of industrial development. With the old method of a waterwheel driving the machinery of a mill, the industry was necessarily located close to the spot on the river where power could be developed. In California, the miners brought water in flumes and ditches twenty to thirty miles to operate their wheels at the mills. Now the power plants are located

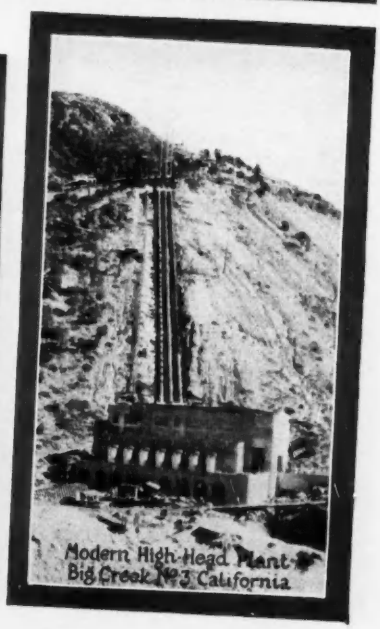
World's Largest Hydro-Electric Plant
Queenston - Chippawa, Ontario

Outstanding Hydro-Electric Developments *at the close of the* Half Century

Complicated construction for a modern plant
Wilson Dam, Muscle Shoals

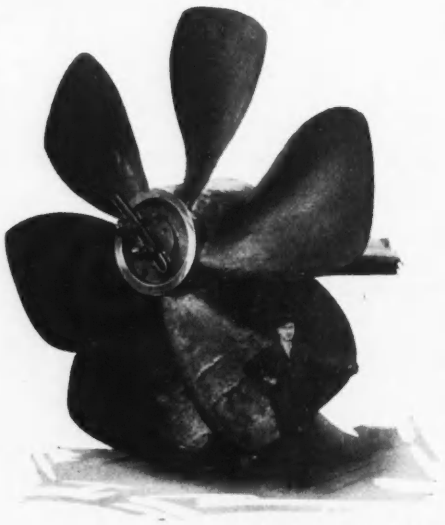
Head Plant in America
t head El Dorado Plant

Low-head Plant using propeller type wheels, Shawinigan Falls, Quebec


Modern High-Head Plant
Big Creek No. 3, California

to suit the best conditions for generating energy and the transmission line extends hundreds of miles to the spot where the energy is used. Industry has been to a certain extent decentralized and any tendency towards centralization is due to other causes, as labor supply, etc. On the other hand, the uses of power have been widely extended. No more beneficial use can be cited than that of pumping water for irrigation or drainage. In California, which state produces the greatest amount of electric energy of any in the Union, and where the per capita use is several times that of any other state, electricity is used in places remote from large cities for flour mills, mines, gold dredges, cement mills, etc., and on farms for pumping, light, milking and minor uses requiring power.

In the end, engineering consists of directing the forces of nature to the service of mankind. Hydro-electric power has become a servant that does much of the drudgery formerly done by hand, and in this manner confers a supreme benefit upon humanity.



28,000 hp., 16 ft. diam.
Manitoba Power Co.

WORLD'S LARGEST PROPELLER TYPE WATER WHEEL

WHAT of the future? Given the same conditions of individual freedom, there is no doubt but that progress will continue unabated. There are, however, tendencies of the present which alarm those who concern themselves with human affairs. The industrial age has built up, in many lands, populations centered in great cities, the numbers of which are far beyond the capacity of the land to support. A complex system of transportation supplies the need of food grown in distant lands and power systems minister to their needs. In the very complexity of modern life lies a danger, for, once dislocated, the delicate machinery is difficult to restore. The struggle of industry to establish itself since the close of the World War is a measure of the blow it received. Democracy is in the ascendant, but while the problems of human life grow more and more complex, it has evolved no method by which the able men of the nation can render service in solving those problems. In fact, as time goes the reverse is true and there is less ability in government at a time when the demand for it is greatest. Industry and engineering have created the modern world, but do not control it. Probably the most dangerous tendency of the time is the concentration of power in the hands of the government. It is dangerous because the power is centered in weak and inefficient hands.

AN ALARM over the dissipation of the nation's resources has led to a false idea of conservation. In no place have the bad effects been more apparent than in hydro-electric engineering where for a number of years the efforts of state and national government have been centered on hampering and restricting development. No such development of industry such as the past has witnessed is possible under the scheme which smothers all ambition, all enterprise, under the blanket of officialdom.

However, while the clouds of doubt obscure the future, the skies of the secure past are clear. The lifetime of men yet living covers the period under review and some Nestor of the profession, some Freeman or Herschel, looking backward over the accomplishment of the half-century may as truly say as did Aeneas of the fall of Troy,

"All of these things have I seen
And of many of them have I been."

Municipal Engineering

1. Urban Growth and Progress

By M. N. Baker

Associate Editor ENGINEERING NEWS-RECORD

THE FIFTY largest cities of the United States in 1870 had a total population of 5,773,000. By 1920 these cities had grown to a combined population of 22,705,000 and New York City alone had 5,620,000 inhabitants, or somewhat more than the population of the 44 largest cities of 1870. In 1920 the population of the 50 largest cities of the country was nearly 38,000,000. There were only 14 cities of 100,000 in 1870. Together they would have made a city of 4,113,000. In 1920 no less than 76 cities had reached the 100,000 mark with a total of almost 33,000,000 people.

Municipal activities were so limited in scope in the earlier decades that up to and including the Census of 1870 the dividing line between urban and rural population was 8,000. On this basis the number of urban places increased between 1870 and 1920 from 226 to 924, the urban population from 8,100,000 to 46,300,000 and the percentage of urban to rural from 20.9 to 43.8. By 1880 urban life had become so much more intense that the urban classification was extended to embrace all incorporated places of 2,500 and all towns of that size in certain New England states. Thus enlarged, our urban population on Jan. 1, 1920, lived in 2,787 cities, villages and towns and totaled 54.3 millions or 51.4 per cent of the entire population. This falls short of completing the picture, for there were in 1920 many thousand incorporated places of less than 2,500 people, each functioning municipally in some degree. The group of smaller incorporated places reached the high total of 12,905, and had a total population of about 9,000,000, both number of places and population having doubled in the last three decades.

What we have to view, then, in our larger picture of 1924 is some 16,000 incorporated places of from 6,000,000 to 100 population with a total population of well toward 64,000,000 or nearly 60 per cent of that of the entire country.

The relative extent of the engineering services rendered in 1874 and 1924 would be surprising if it could be exhibited. The larger cities had pavements, water-works, sewers, gas lights, horse railways, fire departments or rival fire companies in 1874 but many places of considerable size lacked these services entirely or had them only as crude beginnings. There were no electric lights, no telephones, almost no water purification, no sewage treatment, little city cleaning.

The commonest and most satisfactory municipal engineering service in 1874 was public water supply but even this was lacking in 8 of the 50 largest cities shown by the Census of 1870, including Milwaukee. Altogether 422 places large and small had water-works in 1875 compared with only 17 at the close of 1800. By 1896 the country had 3,200 water-works supplying 3,950 places. The yearly rate of growth of water-works in numbers from 1891 to 1896 warrants the assumption that by now 10,000 incorporated places are supplied with water from some public source.

NO ONE knows the number of sewerage systems in the country at any given date. Of the 1,960 places in the United States that had water-works in 1889 the best data available indicate that about 600 had sewerage systems. Corresponding figures for Canada are 87 water-works and 36 sewerage systems.

In 1901, of 1,524 places which by the Census of 1900 had a population of 3,000 and upwards, 1,096 had sewers for the removal of household wastes, compared with 1,475 places which had water-works, 1,471 with electric lights, 1,466 with telephones, 981 with gas works, and 928 with street railway service. Eight cities of 20,000 population or more had no sanitary sewers in 1901, including Baltimore and New Orleans.

Garbage and refuse collection in any systematic way must have been rare in 1874. As there were no incinerators or reduction plants then, presumably most of the garbage was gathered privately and fed to hogs.

In 1901, of the 1,524 places in the United States of 3,000 population or more by the Census of 1900, incinerators were reported by 75 and reduction works by 22 places, and "burning" by 107 places in addition, the latter meaning for the most part smouldering fires on dumps designed chiefly to get rid of paper, etc.

In 1917 the United States Food Administration gathered garbage and refuse data for 779 places of 10,000 population and over. Of these 526 had systematic collection, 171 had no such service and for 82 places there were no reports. Disposal methods were given for 698 places and 43,684,000 population. Half of these places (345) with a total population of 11,170,000 reported disposal by feeding (mostly to hogs); 102 places with a population of 7,032,000 reported incineration; 37 places with 18,554,000 population reported reduction, and 214 places with 6,928,000 population stated that their garbage was "burned," buried or dumped. These figures are the totals for the cities in each class, not populations actually served.

War and post-war conditions led to the closing of some of the reduction works, and to the abandonment of others and to a decline in hog feeding. Today it seems unlikely that

Sketch by Stauffer from Eng. News, June 28, 1884

THE FIFTY LARGEST CITIES OF THE UNITED STATES

As shown by the Census of 1870

Rank and Place	Population to Nearest Thousand 1890	1920	Year Water-Works Built	Typhoid Death Rates per 100,000 Aver. 1880–1889†	1922**	1923**
1 New York	942	5,620	1776	23	27	2.3	2.4
2 Philadelphia	674	1,824	1800–0	59	68	2.8	1.7
3 Brooklyn*	396		1856–9				
4 St. Louis	311	773	1831	40	38	3.3	4.4
5 Chicago	299	2,702	1840	34‡	55	1.1	1.9
6 Baltimore	267	734	1807	59	48	4.1	4.3
7 Boston	251	748	1652	42	46	1.4	1.0
8 Cincinnati	216	401	1820	70	66	3.2	3.2
9 New Orleans	191	387	1833	30 ('81)		10.3	8.7
10 San Francisco	149	507	1856–9	36	46	2.2	3.0
11 Buffalo	118	507	1852	68 ('81)		3.8	4.3
12 Washington	109	438	1853–9	53	74	5.0	6.0
13 Newark	105	415	1800	53	54	2.7	2.3
14 Louisville	101	235	1857–60	66	87	8.0	3.5
15 Cleveland	93	797	1756–4	44	59	2.2	1.7
16 Pittsburgh	86	588	1826	136	108	5.4	3.7
17 Jersey City	83	298	1852	26	69	2.0	1.6
18 Detroit	80	994	1836	54 ('82)		5.1	4.0
19 Milwaukee	71	457	1872–3	37	32	3.1	1.0
20 Albany	69	113	1878 or 9	91 ('84)		0.9	3.4
21 Providence	69	238	1872	50	62	0.0	0.8
22 Rochester	62	296	1872–6	23	34	2.6	1.9
23 Allegheny*	53		1865	56	90		
24 Richmond	51	172	1830	61	75	5.0	5.5
25 New Haven	51	163	1860–2	29	38	7.1	4.6
26 Charleston	49	68	1876–80	112	86		
27 Indianapolis	48	314	1870			5.4	2.6
28 Troy	46	72	1833	21 ('84)			
29 Syracuse	43	172	1829	19 ('84)		1.7	2.2
30 Worcester	41	180	1798	53	28	3.2	2.6
31 Lowell	41	113	1872	37	78	2.6	2.6
32 Memphis	40	162	1872	59 ('83)		8.9	13.6
33 Cambridge	40	110	1837	19	33	0.9	3.6
34 Hartford	37	138	1854	31	46	2.8	0.7
35 Scranton	35	138	1857	26	42	1.4	1.4
36 Reading	34	108	1819–21	49	44	9.2	2.7
37 Paterson	34	136	1856	28 ('85)		3.2	2.9
38 Kansas City	32	324	1873 or 5	25 ('98)		5.2	7.1
39 Mobile	32	61	1840			4.2	6.0
40 Toledo	32	243	1873–4	36			
41 Portland, Me.	31	69	1869	8 ('87)			
42 Columbus	31	237	1870	44 ('89)		1.2	4.6
43 Wilmington	31	110	1804	57	72	8.7	2.6
44 Dayton	30	153	1869–70	36	41	3.7	3.6
45 Lawrence	29	94	1873–5	69	83		
46 Utica	29	94	1849	50	29	4.9	1.0
47 Charlestown*	28		1876–80				
48 Savannah	28	83	1853–4				
49 Lynn	28	99	1870–2	68	41	1.0	2.0
50 Fall River	27	120	1871–4	71	65	3.3	4.1
Total population	5,773	22,715					

* Of the three places not appearing in the list of 1920 populations, Brooklyn is included with New York City, Allegheny with Pittsburgh and Charleston with Boston.

† From Johnson's "Typhoid Toll." **From Census Bureau, except that Hartford, Scranton and Reading figures for '22 and '23 are from *Jour. Am. Med. Assoc.*

‡ Chicago typhoid death rate, 101 in '81 and 172 in 1901.

more than a thousand municipalities, if so many, have city-wide garbage collection with disposal by some improved method. Much remains to be done before the collection of garbage, miscellaneous refuse and ashes is completely, satisfactorily and economically done, while the disposal service is ever shifting and in many other respects unsatisfactory.

Another municipal service of slow development is street cleaning. In 1874 little such work would have been feasible with the small mileage of paved streets of that day. Sweeping machines came slowly into use. By the late eighties combined sweeping and loading machines were being promoted but made slow headway.

In 1901, 1,374 of the 1,524 places of 3,000 population and over in the United States reported street cleaning service but to an unspecified extent. Day labor and hand cleaning were the rule. Thus 1,263 places reported day labor against 86 contract work and 25 both day and contract. Hand cleaning was reported in 929 places against machine cleaning in [illegible] but 315 places reported both.

The Oldest Method of Garbage Disposal

In Piggy, Worcester, Mass. Established 1871

Ready for the down trip

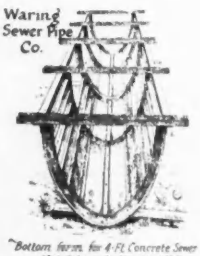
at Ontario, Calif., in 1890

A notable change in the entire city cleaning service in the past two decades, as in fact in fire department and other service, has been from horse- or mule-drawn to motor-driven apparatus.

In the eighties and nineties central heating stations were built in such numbers as to give promise of becoming common. The forerunner of these seems to have been built in the late seventies at Lockport, N. Y. By 1901 there were known to be 122 of these stations, in 119 places of 3,000 population or more and 8 in smaller places. The extension of this service until it became as common as central lighting would have been a boon but difficulties inherent to the city-wide distribution of heat by means of steam or hot water were so many and great and the competition of coal, gas and electricity so severe that central steam and hot water heating was checked.

In percentage of urban population amply supplied by the municipal services mentioned and others that of necessity have been passed over unnamed, the United States leads the world today, as it has for some time past. Outside of Canada, England and perhaps some other British Colonies and a few of the countries of Continental Europe, municipal engineering services are still scanty as to both percentage of cities and of population served. Even as regards water-works much remains to be done abroad by the engineer, the contractor and the supply man, while sewerage, garbage, paving and other services present still larger opportunities.

America should not be over boastful. Although much has been done the service in no municipal field is complete. Every dollar of the millions that have been spent in some fields needs to be doubled and in others to be multiplied three-, five- or ten-fold before every urban dweller can be served reasonably well. Just how far America has advanced towards quantitative and qualitative completeness of municipal service no one can say, for we have no agreed standard for either, much less a body of data to set against the standard.



"Bottom form, for 4-Ft. Concrete Sewer
Middleborough, Ky., about 1891

Even in so vital a matter as the nation's health, although we have tentative standards in the way of total and some specific death rates, the whole country is not even now within the registration area. Officially this area dates from 1880, when it comprised only 17 per cent of the population of the United States, against 82 in 1920. Within the limited registration area of 1880 the general death rate was 19.8. In 1920, in the much larger area, it was 13.1 and still falling. It seems safe to say that the average urban death rate of fifty years ago was double what it is now.

The general death rate cannot be reduced to zero, but for some of the communicable diseases zero is the aim and near zero attainable. For several years typhoid has been so rapidly decreasing as to suggest an approach to the vanishing point. Now and then a year passes with-

out a single typhoid death in cities of considerable size—as witness Providence, New Bedford and Yonkers in 1922 and Norfolk in 1923, all cities of over 100,000 population.

From 1910 to 1923 the average typhoid death rate of the 57 cities of 100,000 population or more for which figures are available fell from 19.59 to 3.45 and the total typhoid deaths from 4,114 to 946. The corresponding total populations were 21 and 27.4 millions. For the entire population the typhoid decline from 1910 to 1923 has not been so great but in the 50-year period under review it has probably been doubly great; in round numbers, to be moderate, say 25 per 100,000 or 250 per million. This figure, applied to 110 millions of people, urban and rural, means a saving for 1923 alone of 27,500 typhoid deaths. Many agents and factors have entered into this saving. No mean part has been played by engineers and other sanitarians in the municipal, the state and the federal health services.

SPRINKLING FILTERS, FITCHBURG, MASS.

Intermittent Filter Outlet Clinton, Mass.

2. Sewerage and Sewage Disposal

By Harrison P. Eddy

Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

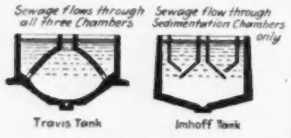
SEWERAGE systems worthy the name and the entire art of sewage treatment in America have come almost wholly within the last half-century. In 1874 combined sewers were the rule. Little if any sewage was then pumped. Empirical formulas were used to compute storm flows. The materials of construction were brick for large sewers and vitrified clay or cement-mortar pipe for small ones. The nearest body of water was the only means of disposal practiced, and that with little regard for either its diluting volume or for whether it was used for human consumption. Since 1874 the separate system has been introduced. Pumping sewage has become common. Empirical formulas for runoff have multiplied, then given place to the rational method. Concrete has come into wide use for sewers, both large and of medium size, and various forms of segmental tile have grown in favor. Most notable of all has been the change in sewage disposal since 1874. First closer attention was given to disposal by dilution. Then came treatment by broad irrigation, chemical precipitation, intermittent sand filtration (chiefly in New England); the septic, Travis and Imhoff tanks; fine screening; the contact bed and the sprinkling filter; and latterly, but as yet slowly, the activated-sludge process, with its promise of sludge utilization.

In 1874, J. Herbert Shedd reported upon sewerage for Providence, R. I., his report containing the first thorough analysis of the relation of maximum rainfall to size of sewers. Three years earlier, construction of the Providence sewerage system had been started, after plans by Mr. Shedd. For many years this system served as a model. In 1884, Samuel M. Gray, forerunner of many American sanitary engineers in visiting Europe, reported upon intercepting sewers and sewage disposal for Providence, recommending treatment by chemical precipitation. His recommendations were approved by Joseph P. Davis, Rudolph Hering and Robert Moore in 1886, but the treatment plant was not completed until 1901. In 1875, a commission composed of E. S. Chesbrough, Moses Lane and Charles F. Folsom, M.D., reported upon the sewerage of Boston, preparing the way for the present Metropolitan sewerage systems of Boston and adjacent municipalities—but not until years after the Boston main drainage works, with its large pumping plant and other novel features, had been put in use in 1884. A particularly noteworthy report, made by Rudolph Hering in 1881 to the National Board of Health upon an investigation of European sewerage practice, contained the first American analysis of all the main problems of sewerage.

The best known and most widely empirical storm flow formulas used in this country in the early days were those of Hawksley (London, 1857); Bürkli-Zeigler (Zurich, 1880); Adams (Brooklyn, 1880); McMath (St. Louis, 1887); and Hering (New York diagrams, 1889). Emil Kuichling, in 1889, advocated the use of the rational method for the estimation of storm-water flows, pointing out that the rate of runoff at any point is dependent upon rate of rainfall and time required for the water to reach the drain.

IN AMERICA the earliest separate systems were built in 1880 by Benezette Williams for Pullman, Ill., and by Col. George E. Waring, Jr., for Memphis., Tenn. Much controversy raged around the Waring installation at Memphis, the maintenance of which proved unsatisfactory due to the small size of pipes used and to the almost complete absence of manholes. Early

SPRINKLING FILTERS IN WINTER, EDMONTON, ALBERTA



Two-Story Tanks

experience and controversies, however, resulted in the adoption of the policy of installing the system deemed to be best adapted to local conditions.

David E. McComb, at Washington, was the first American engineer to build, in 1885, large sewers of concrete. Important changes in methods of sewer construction have been caused by the shortage and high cost of labor and by the substitution of concrete for brick. The old method of excavating by hand and the use of stagings in deep trenches was first modified by the use of bucket machines. Later, upon very large work, the steam shovel was employed, then the dragline and recently upon the smaller work the excavating machine has very largely supplanted manual labor. These changes have been accompanied by progress in methods of handling water. The old hand-operated diaphragm pumps, while still useful, have been supplanted in many cases by power pumps; hand drilling has given way to power drills, first of the tripod type and then of the hammer type; motor-driven concrete mixers have largely supplanted hand mixing; and collapsible forms now often take the place of the old wooden profiles and centers. In the field of maintenance, by means of improved tools and equipment the cleaning of sewers and catchbasins has been developed to a moderate degree of efficiency.

In 1872, William R. Nichols, professor of chemistry at the Massachusetts Institute of Technology, and George Derby, M.D., secretary of the first State Board of Health of Massachusetts, organized in 1869, reported for the State Board of Health of Massachusetts upon the subject of sewerage, sewage disposal and stream pollution. In 1875, J. P. Kirkwood made an examination and report upon the contamination of Massachusetts streams. In 1887 Rudolph Hering began the investigations which led to the construction of the Chicago drainage canal.

Among the earliest to advocate the reasonable use of streams for the dilution of sewage was Dr. Hering in connection with the Chicago problem, although flushing of the North Branch of the Chicago River began in 1880, while in 1888 flushing tunnels were put in use at Milwaukee. The Chicago Drainage Canal was put in use on Jan. 2, 1900.

As early as 1876, sewage irrigation was practiced at the State Insane Asylum at Worcester, Mass. In 1881, Benezette Williams installed broad irrigation for Pullman, Ill., while in 1889 broad irrigation was adopted at South Framingham, Mass., after the plans of S. C. Heald. Broad irrigation is still used in California, notably at Pasadena, for walnut and orange groves, and for institutional plants in New Jersey and Pennsylvania, but these cases are exceptional.

Lawrence experiments of the Massachusetts State Board of Health in 1888 and 1889 demonstrated in this country the principles underlying the oxidation processes of sewage treatment. Intermittent filtration has been confined largely to the New England states where the character and extent of the sand deposits makes such a method reasonably inexpensive but even there it is now in less favor than formerly.

The first chemical precipitation plant was installed in 1889 in East Orange, N. J., from plans of C. P. Bassett, the second at Worcester, Mass., in 1890, by C. A. Allen, city engineer, and the third important plant, at Providence, R. I., went into service in 1901. The East Orange plant, with its supplementary land treatment which gave rise to much local complaint, was soon abandoned for a connection with a Newark sewer leading to the Passaic River. Worcester is now building a large Imhoff tank and trickling filter to replace the present chemical precipitation and intermittent filter installation.

WHAT have been termed antecedents of the septic tank appear to have been first used in America in 1876 at the State Insane Asylum in Worcester, Mass., in connection with broad irrigation; at Lawrenceville, N. J., for a private school in 1882; and at Concord, Mass., for a reformatory in 1883. At Urbana, Ill., in 1894, and at Champaign, Ill., in 1897, A. N. Talbot built tanks very similar to the type later to be called septic tanks. About 1905, F. Herbert Snow and F. A. Barbour designed a treatment plant for Saratoga Springs, N. Y., which included septic tanks. The owners of the Cameron septic tank patents brought suit against the city and the Court of Appeals found for the plaintiffs.

The most notable advance in tank treatment of sewage resulted from the work of Travis in England and Imhoff in Germany who developed some twenty years ago the two-story tanks. Due largely to its early advocacy by Dr. Hering, the Imhoff or Emscher tank has been widely adopted in the United States, the earliest installation being the Madison-Chatham, N. J., plant, in 1911, while the first large tanks were built at Atlanta, Ga., in 1912.

In the early nineties contact beds were developed in England and in the late nineties and the early part of the present century they were adopted in this country but there have been comparatively few large contact bed installations in the United States. The earliest was a small plant at the Glenview Golf Club (near Chicago) in 1898-99. Installations were made in 1902 in Mansfield, Ohio, and Plainfield, N. J.

The first municipal trickling filters to be put into operation in the United States (January, 1908) were those at Reading, Pa., designed by Rudolph Hering and George W. Fuller. Today trickling filters used in conjunction with Imhoff tanks are probably in more general use than any other type of treatment.

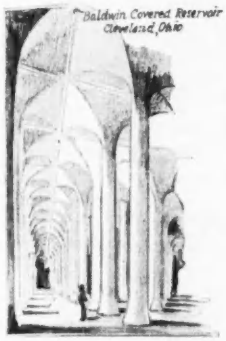
The beneficial effects of sewage aeration, as demonstrated by various American workers and particularly at the Lawrence Experiment Station in 1912 and 1913, were verified by the English investigators, Gilbert J. Fowler and E. M. Mumford. It remained for their countrymen, E. Ardern and W. T. Lockett, in 1914, to establish the beneficial effects of aerated or activated sludge and to suggest the treatment of sewage by the activated-sludge process. Elaborate experiments upon this process have been carried out at Milwaukee since 1914 by T. Chalkley Hatton and subsequently at the Uni-

Sewer Cleaner, Walsall England
from Eng News Nov 27 1869

versity of Illinois by Edward Bartow and F. W. Mohlman in 1915 and at Cleveland in 1916 by Robert Hoffman, R. Winthrop Pratt and George B. Gascoigne. Among the comparatively few activated-sludge plants in use in this country, the first was a small one built at San Marcos, Texas, by Ashley F. Wilson in 1916. The earliest large plants were the two of 5- and 10-m.g.d. capacity at Houston (1916-17). There are also two plants at Chicago, with others projected. A notable plant at Indianapolis is nearly completed and Milwaukee expects to complete 80-m.g.d. plant within a year.

Grit chambers were first used at Worcester in 1904. An important development has been that of mechanical screens, beginning with the Weand screen at Reading, Pa., in 1908, followed by the Riensch-Wurl screen at Rochester in 1916, New York in 1917, and elsewhere, and the Dorrco, link-belt, chain-belt and similar screens at various other places.

Disinfection of sewage began in this country at Brewster, N. Y., where an electrolytic plant for the production of chlorine from brime was installed in 1892. It remained, however, for Phelps about 1909 to demonstrate scientifically the efficiency of hypochlorite of lime for the disinfection of sewage and water. The use of hypochlorite has generally given way to that of liquid chlorine. Providence uses hypochlorite for the disinfection of effluent from its chemical precipitation plant and Cleveland is equipped to apply liquid chlorine to Imhoff tank effluent at the westerly treatment plant and to raw sewage at the easterly outlet.


Baldwin Covered Reservoir
Cleveland, Ohio

PROBABLY the most unsatisfactory aspect of the sewage treatment problem is failure to provide for proper operation of plants built at large expense. In some cases this neglect has resulted in substantial abandonment of plants due to lack of funds. In a few places this need has been met successfully by charges upon water takers, as at Brockton, Framingham, and Concord, Mass. In Ohio a recent statute gives the State Department of Health authority to *require* a municipality to appropriate funds for sewage-works operation.

The best single illustration of advance in the art of sewerage and sewage disposal during the last fifty years is a comparison of the space required to treat the sewage from a city of 600,000 by three different systems: (1) Settling tanks, sludge beds and intermittent filters would require not less than 800 acres and occupy 140,000,000 cu. ft. of space; (2) Imhoff tanks, sludge beds and trickling filters, about 60 acres and 17,000,000 cu. ft.; (3) and an activated-sludge plant, about 10 acres and 5,000,000 cu. ft.

3. Public Water Supplies

By Allen Hazen

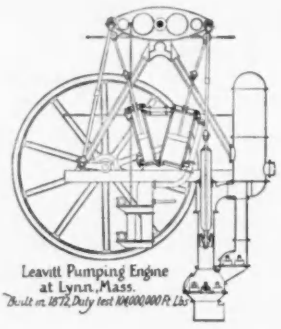
Of Hazen & Whipple, Civil Engineers, New York City

FIFTY years ago most of the large cities of the United States had public water supplies. Those that did not, as well as most of the small cities and nearly all the towns and villages of that day, got water where they could much as had been done in the earlier centuries. Some of the larger cities had notable water-works systems that were delivering water that would be considered of good quality today. The average quality of the public supplies then in use was perhaps higher than it was two or three decades later, after sewage pollution became more common. Ground waters were used by few cities, more generally the smaller ones, as is still the case. Raw river water was common. These river waters were not so bad as present conditions would indicate. Sewerage systems were fewer and less extensive than water-works and where there were sewers only a small part of the population was connected with them. Pollution by manufacturing wastes was relatively unimportant.

In 1874 some of our rivers, since highly polluted, were so comparatively pure that water taken from them without treatment did not seem to be injurious to the public health. In a number of instances the death rates dropped with the new water supply. This indicates that the unfiltered river water of those days was less injurious to those who drank it than the water from the city wells which it replaced.

In the first two decades of the half-century that we are considering there was a period of greater relative water-works construction than before or since. Water-works were built both by municipalities and by private companies. There were a number of reasons for this activity. It was at a time of prosperity that came in the years after the Civil War; there was the advance in the standards of living and in the desire for modern improvements. The return to the gold standard in money may have contributed. The whole water-supply art developed with this activity, and it became possible to do things that had not been possible before, and to do old things more easily.

Fifty years ago the Cornish engine, as developed in England, represented the highest type of pump efficiency. The first engine with a Corliss valve was exhibited at the Philadelphia Centennial in 1876. This was followed by the development of the triple-expansion vertical fly-wheel pump which operated at a higher velocity, cost less and occupied less space. In recent years the remarkable development of centrifugal pumps driven by steam turbines has almost driven reciprocating engines from the field. During the fifty-year period there has been a considerable increase in efficiency but the decrease in size and space required and in the cost of equipment has been much more striking than the increase in efficiency. The pump of today has scarcely doubled the efficiency of its predecessor of fifty years ago but it occupies scarcely a tenth of the space and its weight and



Leavitt Pumping Engine at Lynn, Mass. Built in 1872. Duty test 104,000,000 Ft. Lbs.

relative cost are correspondingly less. The use of centrifugal pumps direct-connected to electric motors has made rapid progress in late years, beginning where cheap electricity from water power was available but extending in many cases to places where electricity must be generated in central stations by steam equipment.

The modern development in the pipe industry had already begun in 1874. Cast-iron pipe, which had been costing $70 or more per ton in the years after the Civil War, had already fallen in price to between $50 and $60 per ton. Pipe made of thin wrought-iron sheets surrounded by and lined with cement mortar had been much cheaper than cast-iron pipe and still continued to be widely used during the early years of the period. As the price of cast-iron pipe continued to fall its use extended and it displaced the cheaper kinds of pipe and became standard. Not only that. The resulting decrease in the cost of construction was an important element in the rapid building of water-works in the smaller communities. This statement would not be complete without adding that cast-iron pipe after falling in price to as low as $17 per ton, again increased in price, and during and after the World War it reached the prices that had prevailed after the Civil War, and the selling price today is higher than fifty years ago.

As water-works systems were extended to the smaller cities and to the towns and villages, and as they gradually reached to more and more of the houses in the communities they served, the sewer systems were also extended, with a resultant increase of water pollution.

The time came in the nineties when it was realized that the wide use of raw river water was causing disease and death. It was found that some of the cities whose death rates had been favorably affected by the introduction of public water supplies from rivers in the seventies were experiencing, twenty years later, high and increasing death rates as a result of the increased pollution of those river waters. This was at the time of our first lessons in bacteriology and the relations between water pollution and public health.

But filtration of public water supplies is older than attempts to meet or correct such pollution. It had its origin in the desire to clean up and make attractive muddy and discolored waters. A few filters were in use in America before bacteriology was understood. When the new tests became available the interesting discovery was made that filters capable of removing color and turbidity also remove a large part of the bacteria. It was also found that those cities which had good filter plants were less subject to water-borne diseases and had lower death rates than other cities similarly situated that used raw water. European practice was distinctly in advance in these early years and many lessons were learned from English, German and French cities from the time of the pioneer report on filtration to the city of St. Louis in the sixties by James P. Kirkwood.

FIFTY years ago Poughkeepsie and the half dozen or less small places that had some rudimentary form of filtration used the slow sand process which had been developed and successfully used in Europe. Rapid filtration was introduced some forty years ago. The results obtained by filtering at a higher rate with the aid of coagulant were such as to warrant the extension of the process to municipal supplies. Coagulation was necessary for both highly colored water and northern and southern swamps and for the very turbid river waters of the middle and southern states but it was not necessary for the clear waters of many lakes, reservoirs and some rivers.

In the period of most active filter construction both systems were extensively employed and much was published about their relative merits. There were patents on certain features of the rapid filters and the companies owning them were active in promoting the use of these methods. For a time the increase in the sand filter plants was more rapid but recently the rapid filters have predominated.

Slow sand filters, serving as they do some of our larger cities, taking water from highly polluted sources, have on the whole produced better water and have done it at lower operating cost. They seem to have had a distinctly better record in the removal of tastes and odors. The processes have changed, and a rapid sand filter plant of today bears little resemblance to some of the plants of its kind first used in municipal service.

A number of river water supplies are in use where the character and extent of the pollution are such as to require double filtration to secure a reasonable degree of protection of the public health. In the interior of the country is a broad belt where the waters are hard. As water purification has developed it has been found possible to secure partial softening in connection with coagulation and other treatments Its use has been adopted by many cities, including Columbus, St. Louis and New Orleans. Softening is a relatively expensive process. It is for this reason that it can ordinarily be used only where all water is sold by measurement and where the rates are sufficiently high to cover the considerable costs that are involved. Softening has brought in train a whole series of secondary problems that are being gradually worked out.

SERVICE reservoirs are used wherever neighboring hills afford sites to equalize the fluctuations in rate of draft at different hours of the day. In early American practice these reservoirs were open to the sky. As long as raw river waters were used, open reservoirs were satisfactory; and so far as the quality of the water stored in them is concerned it was generally improved. When better waters were supplied they deteriorated in quality in service reservoirs. This deterioration is principally due to growths of algae and organisms that grow in the light. Various conditions influence the results, but, in general, the purer and clearer the water the more deterioration of quality is ex-

Raising 40-in Water Main 0-18 Ft Boston, Mass. from Eng' News, Jan 23, 1886

perienced in open service reservoirs. This has led to the construction of covered reservoirs in many American cities. It is curious to note that the old Roman service reservoirs were covered, and when we compare the plans for our newest structures with those of the Roman reservoirs, the improvements in design in all these centuries seem relatively unimportant. The Roman reservoirs still standing are evidence of the skill of their builders. May the water-works structures now building in America last as long!

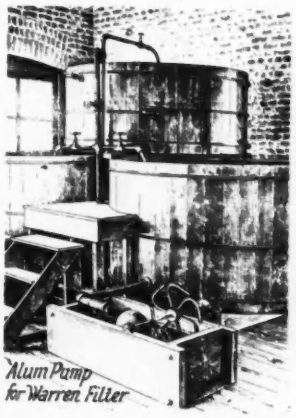
The water delivered by public water-works systems today is a product whose quality is carefully controlled and regulated by chemists and bacteriologists with the aid of extensive and expensive filter plants and equipment. Water produced by such methods is not as free as air but is a commodity of ascertainable and substantial value. Where the fixture system of charging for water was in use the consumption increased at a progressive rate in some of our cities until several times as much water was wasted as was used. This still continues in a few cases.

The water meter has furnished the only successful method by which useless waste of water may be controlled. The 50-year period has seen the development of the meter system since its first beginnings. The meters first used had their limitations in accuracy. They had to function with water that carried turbidity and sediment. To operate at all the parts had to be built loosely and much water passed between without registering. Accurate measurement depends upon having clear water free from sediment. As the qualities of the public water supplies have improved it has been possible to make water meters with small clearances that record more accurately. The meters of today do what no meter could have done in the early days and this is largely possible because of the better average quality of the water

Jawbone Siphon, Los Angeles Aqueduct

The first meter rate schedules were often curious affairs with many unjust discriminations. This business is now being standardized. Rate schedules that are equitable to all classes of consumers have been developed. The use of such improved meters has increased very rapidly and the time seems not far removed when the last of the fixture rates will disappear. That will be a fortunate day for the water-works business.

Fifty years ago a considerable proportion of the water-works systems were owned by companies. In the years of rapid construction the proportion of works built by companies was maintained or increased. After that there was a reaction to public ownership. Fewer new works were built by companies and many plants were sold by companies to the municipalities that they served. In some cases these works were sold by agreement. More frequently the exchange was brought about by eminent domain followed by long and expensive litigation.



Alum Pump for Warren Filter

Some water companies have been successful through a long term of years and render service that compares most favorably with that of municipal plants. A substantial minority of the important water supplies of the country are still in private ownership. Among others, San Francisco, Indianapolis, Oakland, Birmingham, New Haven, San Antonio, Bridgeport, Scranton and Paterson may be mentioned.

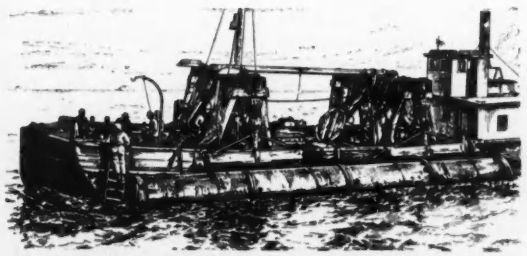
In this 50-year period every city in the country has built or has improved its water-works. In New York City there was first the construction of the New Croton Aqueduct with great impounding reservoirs, and more recently the Catskill Aqueduct, the largest undertaking of its kind ever carried out. Boston and its neighboring towns through the Metropolitan Water Board have built a splendid new source of supply to meet combined needs, and in the 30 years since it was built the business has grown until further additions must be made.

Chicago has extended her intakes far out under the bed of Lake Michigan to get water farther from the pollution of the shore; and on the other hand has made an effort nowhere else in the world equalled and has kept the major part of her sewage out of the lake by diverting it with some of the lake water to streams flowing to the Mississippi River.

Of the larger cities that have built over their old works with filtration and treatment of water, may be mentioned: Philadelphia, Detroit, St. Louis, Baltimore, Pittsburgh, Washington, Cincinnati, Minneapolis, Kansas City, Indianapolis, Toledo, Columbus, Louisville, St. Paul, Atlanta, Omaha, Paterson, Trenton, Albany, Wilmington, Reading and Fort Worth.

Los Angeles, a city which hardly existed 50 years ago, has claimed the attention of the whole country by building an aqueduct 250 miles long, bringing an abundant supply of water from a remote source on the western slope of the Sierra Nevada Mountains to support her wonderful growth in population and in industries.

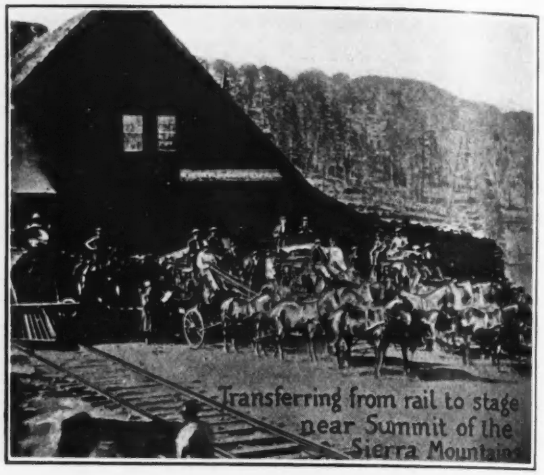
There is a temptation to follow down the list, but to do it would be practically to make a catalog of the cities of the country. Every growing city must increase its water supply. Our cities have grown rapidly. Our natural water resources are great, and their development is keeping pace with the ever-increasing requirements and advances of the twentieth century.



Towing 60-in. Cast Iron Intake Pipe, Milwaukee, Wis.
from Eng'g News, Sept. 19, 1895

Central Pacific Water Train on desert construction

Freight wagons leaving California for the Nevada Desert



Transferring from rail to stage near Summit of the Sierra Mountains

Railroad Engineering Through the Half Century

By William Hood

San Francisco, Calif., Retired Chief Engineer, Southern Pacific Co.

TO THE engineer who looks back over the past fifty-year period of railroad construction in the United States, from 1874 to 1924, there are apparent great changes in location and construction methods and in the conditions which have governed or influenced railroad development. Although this period did not include the opening of the first American transcontinental line (1869) it has included several succeeding lines and also Canada's first transcontinental railway (1885). Its earlier years constituted an era of extensive construction, largely of a pioneering character, when speed of progress was a primary consideration. It was in this period that American engineers amazed the world by their boldness in both the planning and execution of railroad projects.

Notable records of speed of construction were made when new railroads were being pushed across unsettled country and when light grading, timber trestles, earth ballast and light-weight track material were features of the work. Such rapid work is now among the traditions of railroading. In these days there is no such urgent demand for speed, grading is usually heavier in order to get a profile suitable for economic operation, ballast and track are heavier, and in many cases the progress is slowed up by the construction of permanent structures of concrete and steel.

These spectacular railroad activities were most pronounced in what was then the "Far West," where competition between rival interests for certain routes was aggressive and sometimes even militant, although the hostile red man had almost ceased to be a danger. The East also had its competitions and rivalries, but they were fought in the courts rather than in the field. And it is obvious that in both location and construction, a new line to compete with an existing railroad is a very different proposition from a pioneer line. This early era of rapid expansion was halted by financial depression and when railroad construction again began it was on a less feverish and exciting basis. The closing years of the period have been marked by the reduction of new railroad building almost to the zero point, due to various post-war conditions. However, the railroad system is far from being complete and though there may be but few opportunities remaining for large trunk lines there

are and will be many opportunities for railroads which will give improved service or open up new districts.

A conspicuous and important feature which distinguishes the closing of this fifty-year period is the beginning of an era of railroad improvement, double-tracking and reconstruction, due to the vast commercial growth of the United States, with its almost incredible increase in traffic, combined with an increasing demand for reduction in cost of operation to offset ever rising expenses. It is true that such work is not entirely new, for improvements in line and grade have been in progress for many years. But never before has this work been undertaken on such a vast scale as to be a distinctive feature in railroad development, far overshadowing the actual extension of the railroad system.

THAT extensive relocation is included in this reconstruction and improvement program is no reflection upon the skill or judgment of the earlier engineers. They worked under governing conditions very different from those of the present day, so that necessarily and wisely they built their lines for light loads, limited traffic and low first cost. To the railroad engineer of those early days one of the main principles was to get a line through to a desired point, keeping within at least the letter of instructions as to maximum grades and then building his line as rapidly and as cheaply as possible. To the railroad engineer of today, the operating and economic sides of the transportation problem are vital and fundamental considerations.

For the engineer's first survey of reconnaissance of a proposed railroad route, to determine the general natural features of the region expected to be traversed, the practice of traveling on horseback, by horse-drawn vehicle or on foot, continued until after 1904. Soon after that time the automobile became available and greatly expedited exploration in regions where even very ordinary roads existed, and even on deserts and in open country without roads when the surface of the ground was not too much broken or did not include large areas of soft or drifting sand. Probably the airplane and airplane camera will be of much use in the future.

With all these modern mechanical aids, however, there yet remains, especially in the West, the necessity for trips of examination on horseback and on foot if the engineer is to obtain such exact and reliable knowledge of the topography as to enable him to determine practicable grade systems and an approximation as to the construction cost.

The general introduction of the pocket hand-level about fifty years ago was an important assistance in judging possible grade rates, and although this instrument has been modified in detail it has not been materially improved as to results obtained. Some of the early work of explorations of large uninhabited areas with saddle horses and supply pack train, using astronomical methods for fixing principal points and supplemented by moderately accurate triangulations and mercurial barometer observations and skillful sketching of topography, produced maps of previously unexplored regions with an accuracy for all required uses that would hardly have been expected or believed to be possible under the difficulties and often severe hardships encountered.

The ideal instrumental preliminary survey on rough and steep ground is now and always has been made with the same degree of instrumental and measurement accuracy as the subsequent final location of the center line of the railroad. The preliminary survey was, and still is, so placed on the ground as to have its profile a close approximation to the final center line of railroad and a fair basis for preliminary estimate of quantities. The final location survey, or the staking out on the ground of the center line of the railroad as planned, involves (at least in the ascent or descent of a considerable elevation, like a mountain range or even a lesser height) fixing permanently all construction quantities and the character of future operation of the road in respect to tonnage ratings of locomotives.

That the importance of this work and its after consequences in relation to the operation of the railroad seems not to have been generally understood as early as fifty years ago, is evidenced, amongst other things, by the occurrence of stretches of grade rate steeper than the general ruling grade, by lack of appreciation of advisable relation of valley grade rate and adjacent mountain grade rate, by the omission of reduced grade rates on curves, and by the omission of easements at the ends of curves. These defects have been generally avoided on recent work.

The comparison of alternative routes or portions of routes in reference to their anticipated relative operating costs and costs of construction was not closely formulated in the last century. Except for locomotive and train crews' wages and approximate cost of operating helper engines, the allowances for relative distances, total curvatures and total ascents and descents were based on very general assumptions for obtaining equivalent operating cost values of curvature, grade and rise and fall, expressed in relative equivalent straight and level distances. This method gave approximate relative results when applied to fairly correct data obtained from accounts of operation of a railroad or part of a railroad having a grade system essentially similar to that of the proposed routes that were to be compared. It also gave very good relative results for comparing short alternative lines on the same route.

PRESENT day methods for deciding similar questions of relative operating costs of alternative routes are a considerable advance on those that have been outlined, being based in part on power expenditure quite closely computed. But there is still much to be desired in the way of reliable data, and of methods of computation and application of data so formulated that an office force can readily and reliably obtain the results desired.

During the very active period of railroad building between about 1863 and 1890, work was done partly by unit price contracts but commonly by the railroad company's forces, especially on very large jobs when rapid progress was the controlling consideration. On account of certain characteristics of human nature, these company forces rarely did construction work as cheaply as if it had been done by contract, but the increased cost was justified when unusual speed was necessary.

After about the year 1890 the generally prevalent method was by contract, very few construction jobs requiring sacrifice of cost for extreme speed. Since that date, therefore, there has been seen the growth of important contracting organizations capable of undertaking

Chinese Labor on Central Pacific Main Line

End of Track on Humboldt Plains

Division Headquarters, Cisco, Cal.

Central Pacific Railhead

Building the Transcontinental Railways

Heretofore Unpublished Views

Scrub Juniper-the only fuel available

Living Car of a Superintendent of Construction

railroad work large or small, light or heavy. At first these organizations relied mainly on the "practical" man, but of late years they have shown a growing tendency to have their own engineering staff and not a few railroad engineers have drifted over into the contracting ranks.

On some roads, however, certain parts of the work have always been done by company forces; such, for instance, as tracklaying and surfacing and ballasting. This is especially the case on roads with heavy grading so situated that continuous work of this kind could not be counted on, so that the occasional necessity for breaking up these gangs to do other work and then reorganizing them for track and ballast work makes a prediction of cost of the work difficult on the part of intending contractors.

Under such conditions it then becomes best for the railroad company to assume the chances, rather than to accept a proposal at prices which will make the contractor safe in any event. Similarly, railroads have sometimes employed company forces to build bridge piers when the foundations were difficult or were uncertain as to difficulties and resulting cost, rather than accept a contractor's proposal based on uncertainties.

Making fill with mule carts-1874

Making fill with air dumps-1924

One of the most striking features of the half-century period of railroading is the remarkable development in machinery, tools, appliances and methods employed in railroad construction. At the beginning this development was largely to increase speed of work, but later it has been accelerated by the great changes in labor supply and cost. In the earlier years, the grading of low banks up to about 4 ft. high was commonly done by plowing the side borrow and casting the material into the bank with long handled shovels. Although this was apparently a slow and laborious method, as much as 16 cu. yd. per man in a 10-hr. day as an average for a large gang was not uncommon in favorable soil, while much higher individual performances were recorded. This method of side borrow with berms from 3 to 5 ft. wide was a cause of subsequent serious side washouts in some localities.

Somewhat higher banks were side borrowed with two-horse slip scrapers; but with two horses and driver and cost of plowing this made much more expensive grading than plowing and side casting. Deeper cuts and higher banks were worked with hand loading of one-horse carts, and with stoneboats where needed. This method was capable of effecting very rapid construction if desired, but was expensive in units of labor, animals and appliances per cubic yard. In rock cuts, the drilling was all done by hand labor and the loading and hauling out of the material were done by one-horse carts and stoneboats. Black blasting powder was the explosive generally used, although nitroglycerin was commercially made in 1862 and dynamite was invented in 1866.

Changes in grading methods in later years were in the way of using less labor and more mechanical appliances. The earliest change in this respect was due to the invention of the "Fresno" four-horse scraper, giving a marked reduction in cost of work over former methods, and with a readily obtained increased berm width where advisable as a precaution against side washed banks. The wheeled scraper followed and had advantages where the transport distance was considerable. Thereafter came the bottom-dump wagon, the elevating grader with its wagons or motor trucks, and the modern steam shovel, with attendant light locomotives and dump cars and track and dumping trestle. All of this equipment has tended by the cheapened long hauls to obtain more favorable alignment of the railroad and at less cost than when haul of excavated material was restricted to carts, wheelbarrows and stoneboats.

On lighter grading we still see the scraper teams and dump wagons, but even light work is now being done largely by machine methods which at first were employed only in heavy excavation. Both large and small steam shovels are now used, handling material of all kinds and loading either small dump cars or the modern large air-operated cars. Incidental to this handling of excavated material in bulk is the development of spreader cars to replace large groups of men in leveling and spreading the dumped material. The development of dredges with large capacity bucket and long radius booms, primarily for reclamation levee construction, has enabled railroads to be built cheaply across extensive marsh lands which it would have been difficult and expensive to cross by other known methods.

Although hand drilling of rock cuts is still practiced where expedient, the introduction of readily hauled power air-compressors and power drills, including the well drill, has effected material economies and reduction of dependence on labor. A marked reduction in cost of rock cuts and tunnels has followed the increased use of high explosives, from the first occasional use of nitroglycerin in liquid form, poured from demijohns into drill holes with seeming recklessness, to the general use of varied strengths of dynamite and similar explosives in safe and convenient form.

Haul of construction material and supplies on country roads and over open country was done by horses and mules until the last few years. This also involved similar haulage of the bulky supplies of hay, grain and water for the animals, the amount of such supplies hauled in desert regions sometimes approximating the tonnage of the construction material and supplies. The introduction of motor trucks for this service has been of extreme benefit in the reduction of costs of this sort, particularly in desert regions.

During the past century tracklaying was done mainly by hand work, with the aid of small cars similar to strongly-built push cars. These cars, drawn by horses, carried the track material from the point where it was dropped alongside the track by the supply train, to the continually advancing end of the rails or "head of steel." Perhaps there is no other method known by which so great a mileage of track can be laid per day as in this way, and extraordinary records have been made. But with modern tracklaying devices the work can be advanced on what are generally ample daily distances at less cost and with a much smaller labor force, which last is sometimes a controlling advantage.

The principal causes of reduced speed of tracklaying at the present time, as compared with that of early railroad construction, lie in the heavier ties and rails, the use of tie-plates and of broken joints instead of even joints, which latter were the more satisfactory when railroads were mostly earth ballasted and the track was not kept in specially good surface. On the other hand, as a result of the great reduction in mileage of new construction in recent years some of the once well-known tracklaying machines have gone out of use.

Railroad truss bridges fifty and more years ago were very generally of wood, commonly Howe trusses, excepting on some of the older roads that had some iron bridges in service, a number of these latter following the then English methods of design. Wooden Howe truss bridges persisted on many railroads, especially Western roads, until after 1880, when iron bridges at first and steel bridges a few years later gradually replaced the wooden trusses and were universally used also on new construction in situations where the timber trestle was not permissible.

The rather clumsy outer and overhead erecting traveller of early days was soon replaced by the present erecting appliances, mounted between the chords. In this way, when the ordinary falsework below the lower chords is ready, the process of erecting the bridge ready for riveting is rapid and simple. The modern pneumatic riveting tools, which soon make a permanent structure of the bridge, are an obvious improvement in speed over the former hand-riveting methods and effect a considerable saving in the cost of riveting.

Two distinctive types of structures which have characterized American railroad construction are the timber trestle (both pile and frame) and the steel viaduct, both designed originally to meet requirements of cheapness and rapidity in construction but improved in later years to give greater stability and permanence. The timber trestle, one of the earliest types of railroad structures, is still used extensively, but mainly in the West and with such improvements as treated timbers and ballasted decks. Many of the earlier trestles and viaducts have been replaced with solid fills and permanent culverts, when the need for extensive repairs and renewals made them no longer economical. For low structures, also, the concrete trestle has been introduced in recent years as a substitute for the smaller type of timber pile trestle where the latter cannot be replaced by filling.

In masonry work, the substitution of concrete for stone has been another development that may be termed remarkable. Until the last few years of the past century, railroad builders seemed unwilling to use any material other than a good quality of rock for masonry piers, abutments, culverts and similar structures, although if necessary, a hard burned brick might be substituted.

Concrete made with European cement was resorted to if neither good rock nor burned brick was available. But the prices of reliable European cement were so high that concrete was not a cheap building material, unless with an unusually favorable source of components. With the increased production, lowered price and rapidly improving quality of American cement, it is now not common to see any other than concrete masonry used on railroad construction, if the other materials for the concrete can be reasonably had. As a result of this remarkable development of what is practically a new material, it is now difficult to assemble a force of competent stone masons for railroad construction work.

A new fifty-year period of railroading opens in the present era of improvement and reconstruction of existing railroads, with extensions marking time while waiting for another advance. What changes and conditions this new period will develop can hardly be conjectured, but it may be predicted that they will be as great and as important as those of the period 1874 to 1924.

Professional Progress, 1874-1924

By Francis C. Shenehon
Consulting Engineer, Minneapolis

OUR PURPOSE is to review briefly the last half-century in America, noting the sociological evolution of the profession of engineering, its attainment of group consciousness, its foundation of a library, its growing articulateness in periodical literature, its better college training, its widening bounds, its deepening recognition, its splintering into many breeds and its present tendency to blend its many breeds into a single strong profession.

Half a century ago the beginnings of several national engineering societies evidenced group instinct. The artist-engineers had manifested their individualized group consciousness by forming the Institute of Architects. The geological engineers had organized the Institute of Mining and Metallurgical Engineers. The American Society of Civil Engineers served as the melting pot to blend all breeds of engineers. This earliest national society, instituted in 1852, existed precariously and intermittently during the years prior to the Civil War, and during the period of the war. For twelve years no meeting was held. The real continuing vitality of the society began in the fall of 1867. By the spring of 1868 it had a "local habitation and a name." Volume I of the "Transactions" was published in 1872. In 1880, the American Society of Mechanical Engineers was organized; and in 1884 the Institute of Electrical Engineers. All five of these societies have grown amazingly in membership and in complexity of organization.

THIS historical glimpse serves to accentuate the fact that the half-century just elapsing has witnessed this manifestation of the vital group activity which weaves individuals into the fabric of a profession. And these societies erected habitations as meeting places, they entered into exchanges of technical thought and practice, they were the patrons of technical periodicals, they published their proceedings to be broadcasted over the continent and across the sea, they brought from over the sea the thought and practice of alien engineers and they collected libraries. And technical schools grew stronger in teaching, produced text-books and collected libraries.

All this grouping of men of kindred employment, with the inevitable sequences of meeting places, discussions, periodicals, bookmaking and libraries, is not distinctive of the engineer. The lawyer and the surgeon have similar histories of development. But in this particular half-century science and invention placed in the hands of the engineer instrumentalities which the engineer employed practically and usefully to create the complex mechanism of modern life. Structural steel, first used in the St. Louis bridge in 1874, aluminum, ferro-alloys, the high-head water turbine, the steam turbine, the alternating current generator, long-distance high-voltage transmission, electric light, heat and power, the telephone, the wireless, the trolley, the gasoline engine, the automobile, the airplane, the submarine, the transatlantic greyhound, the Twentieth Century Limited—these are all of this last half-century, and have created broad fields of engineering practice and many kinds of engineering specialists. This is the luck of the engineer of this past half-century, and the practice must go on perpetually but not with such astounding revelations. The coming half-century belongs to the biologist, the biological chemist, the physician and the surgeon.

IN THIS last half-century the population has multiplied two and a half times, while the engineering portion of this population has multiplied as the cube or higher power of this. And the country has grown enormously in wealth, partly created by the contribution of the engineer, and in turn broadening the scope of the engineer's practice and the adequacy of his remuneration. The half-century began with the near recovery of the nation from the strain of the war for the preservation of the Union. And this war made engineers, and these engineers pushed railroads across the continent. And new land areas were made accessible with the response of population influx. Population, land, power transmission, quantity production, transportation and capital all acting and interacting, crowded this half-century with brilliant achievements in material things.

Perhaps however the sociological result means more to the world than the magic of machines. Having in mind the enfeebling effect in the mill towns of New England on men, women and children, Emerson wrote: "Let there be worse cotton and better men." It is certain that the contributions of engineers in the half-century now elapsing have not enslaved men but have added to the wholesome joyousness of life and to the years of life of the people of the country. And the people recognize the contribution of the engineer.

Within the profession itself the influence is still felt of the tall men of 1874, with less standardization in their technical training and greater need of initiative in standardizing practice. For the younger engineers the more highly specialized college training predestined them to work in the branches of the profession rather than in its trunk, and the sales engineer and the managerial engineer are of the sinews of industrialism. Perhaps the majority of engineers are salaried men. In this the profession differs from law, medicine and surgery. The individuality of the salaried man is in a measure merged in his business machine. But the free-lance exists in the consulting engineer; and a new powerful influence exists in the grouping of various specialists in organizations corresponding to the Mayo clinic of surgeons.

The whole profession with its inevitable branch growth has in the closing years of the half-century shown a strong tendency to group organization based on the trunk identity of all engineers. Strong men and group strength make for a great profession.

A Few Paragraphs About Ourselves

Engineer and Surveyor.
April, 1874
ENGINEER-ARCHITECT SURVEYOR.
May 1874-Dec 1874
Jan. 1875 Dec 1875
ENGINEERING NEWS.
Dec 1877 Nov 1880
The Plumber
SANITARY ENGINEER
Dec 1880-Nov 1886
SANITARY ENGINEER
Nov 1886-Oct 1887
THE SANITARY ENGINEER CONSTRUCTION RECORD
1898-1918.
THE CONTRACTOR
ENGINEERING NEWS
THE ENGINEERING RECORD
BUILDING RECORD SANITARY ENGINEER
Engineering News-Record
The Technical Journal as an Institution
Engineering News and Engineering Record Consolidated April 1917 the Contractor Consolidated June 1918
TO VOLUME XXIII
Jan. 1876-Apr 1917 With variations in the subtitle to include American Contract Journal and American Railway Journal
Oct 1887-Apr 1917 With variations in the name Engineering & Building Record and Sanitary Engineer

HERE is the genealogical tree of *Engineering News-Record*. The whole story of that tree was told in detail in the first issue of the combined paper, April 5, 1917. Only the major facts need be repeated in the present statement.

Engineering News, the older of the two major branches, was founded in 1874 by George H. Frost. The first number of the paper—a monthly called *Engineer and Surveyor*—was published on April 13 of that year in Chicago. Its founder, who was also its editor in its early years and who kept possession of the property until 1912, was a Canadian-born American surveyor and engineer, a graduate of McGill University, who was at that time eking out a rather precarious living as a land surveyor in Chicago. His monthly paper was a venture which for several years wavered between mere existence and failure. In its first numbers it was largely local to Chicago and quite thoroughly devoted to surveying as distinguished from engineering or construction. As the chart shows, however, even in its second issue the building profession was recognized and the word "Architect" was added, and in January, 1875, the title was shifted to the *Engineering News* which persisted for 42 years. In 1876 the paper had prospered to the degree of becoming a weekly, and in 1879 it moved to New York. From 1879 to the time of the consolidation in 1917 it remained *Engineering News* with a variety of subheadings, such as *Engineering News & The American Contract Journal*, *Engineering News & The American Railway Journal*, and finally, in 1902, the sub-title "A Journal of Civil, Mechanical, Mining and Electrical Engineering" was adopted.

In its early years, Mr. Frost was the editor of the paper as well as the publisher, advertising solicitor, and almost everything else, but he had various other editors, among whom may be mentioned Lyman E. Cooley, later to become so prominent in Chicago engineering circles, and Julius W. Adams, a past-president of the American Society of Civil Engineers. In 1883 a third interest in the paper was sold to D. McN. Stauffer, who became a joint editor, and in 1887 another third to Arthur M. Wellington, who for eight years was the editor-in-chief. The great growth of *Engineering News* started with Wellington's advent. An experienced engineer, a facile writer, and a great journalist, the new life that he breathed into the paper can be noted even today in going over the pages. Within a few weeks after the

announcement of his coming, the paper took on a new flavor. Mr. Wellington died in 1895 and Charles Whiting Baker, who had been on the paper since 1886, became editor-in-chief, remaining in that position until 1917, when the paper was merged with *Engineering Record*. In 1912, George H. Frost, who had repurchased control, sold the paper as a publishing property to John A. Hill, an experienced technical publisher who retained control until his death in 1916.

Engineering Record, the other main branch of the paper, was founded in New York in December, 1877, as *The Plumber & Sanitary Engineer*. Henry C. Meyer, a manufacturer of plumbing supplies, was the founder and publisher, and the first editor was Charles F. Wingate, a newspaper man but not an engineer. It was a monthly. It was changed to a semi-monthly in 1879, and in 1880 became *The Sanitary Engineer*, a semi-monthly, changed in December, 1881, to a weekly. In 1886 the growing importance of the building field in the paper was recognized by the addition of the words "and Construction Record" and in 1887 the shift was made to the title *The Engineering & Building Record and The Sanitary Engineer*, which became, in 1890, *The Engineering Record* with the subtitle "Building Record & The Sanitary Engineer." The subtitle was dropped in 1910 and the final subtitle "A Weekly Journal Devoted to Civil Engineering and Contracting" adopted. Mr. Wingate was editor of the paper for four years and upon his retirement Major Meyer himself assumed charge of the editorial department, but he was succeeded in the late nineties by John M. Goodell, who had been an associate of Wellington on *Engineering News*. During a period of Mr. Goodell's leave of absence, Alfred D. Flinn, now secretary of the Engineering Foundation, was editor for a year.

Major Meyer sold the paper in 1902 to James H. McGraw, under whose control it continued until upon the death of Mr. Hill the McGraw and Hill interests were consolidated under Mr. McGraw's presidency in 1917. The merger of *The Engineering Record* with *Engineering News*, under the title *Engineering News-Record*, took place on Apr. 5, 1917. Mr. Goodell came back as editor of *Engineering Record* when it was purchased by Mr. McGraw and continued in that position until 1912, when the editorial chair was taken by E. J. Mehren who continued as editor of *Engineering Record* and of *Engineering News-Record* until the first of the present year, when he became vice-president of the McGraw-Hill Co. in charge of the Engineering Unit of that company.

In 1918, *Engineering News-Record* absorbed *The Contractor*, then in its twenty-fifth volume. This paper was a semi-monthly published in Chicago which had started as *The Dirt Mover*.

To Those Who Have Made *Engineering News-Record*

By E. J. Mehren

Vice-President, McGraw-Hill Co., Inc.

IT WOULD not be fitting to allow the Anniversary of *Engineering News-Record* to go by without a tribute to those who have been responsible for the paper's growth and development—George H. Frost and Henry C. Meyer, John A. Hill and James H. McGraw, the publishers; D. McN. Stauffer and Arthur M. Wellington, Charles Whiting Baker and John M. Goodell, the editors. To them the profession and the industry owe the institution that is *Engineering News-Record*. Each of them has placed an impress upon it, and that impress will remain, built into the structure no less certainly than is the core of the oak into the tree.

To the publishers—Frost and Meyer, Hill and McGraw—first credit is due. They were determined to give the readers a magazine constantly improving in value, a better and better journalistic tool. The reading matter, in consequence, saw a never ending improvement in quality, in helpfulness, in scope, in timeliness.

No less important was their ethical attitude. They regarded their enterprise as a professional calling, and despite all pressure refused to allow their reading pages or editorial columns to be governed by any other consideration than truth and the best interest of the readers.

The one policy required faith in the ultimate success of their venture, unbounded energy, masterly patience, dogged persistence. The other, high courage and fixity of purpose and the confidence that if the interests of the readers were stoutly defended and consistently served the readers in turn would give generous support and assured victory over the adverse influences. There were early days of discouragement that would have been fatal to men of ordinary mold, but these stalwart characters carried on—and the fruit is found in the *News-Record* of today.

But the publishers could not conduct the enterprise alone. Competent editors were needed. Fortunate indeed was their selection. They were men of sound judgment, of journalistic perception, of high courage, able writers, leaders in engineering thought, good teachers, able executives. Stauffer, Wellington, Baker and Goodell, the editors, have won places in engineering annals and in the history of technical journalism.

The editorial leaders, in turn, were fortunate in their co-workers; they would, in fact, be the first to pay tribute to the parts played by their associates—M. N. Baker, Tratman, Schmitt, Wight, Hill, Skinner, Barker, Tomlin, DeBerard and Bowers, men of outstanding ability, who molded and have molded engineering thought for many a year.

Nor would justice be done if there were not a word for the others, in the circulation and advertising depart-

ments, who have borne a heavy—though less conspicuous—part in the building of the paper. Particularly have the advertising men played an important rôle. Through their personal assistance to manufacturers and their counsel on the effective use of advertising space they have helped to build those great enterprises which each year have furnished to civil engineers and contractors cheaper materials and better cost-reducing plant and equipment—great factors in lowering, or in these days holding down, the cost of construction to the industry's client, the public.

OBVIOUSLY, the soundest of policies and the best of men are of small value unless the policies are consistently adhered to and developed year by year; the necessary corollary of consistency of policy is continuity of service of men. In this respect, *Engineering News-Record* has been unusually fortunate. In the 50 years of its life, counting the *News-Record* continuous with *Engineering News*, there have been but three publishers and four chief editors; counting *News-Record* continuous with *Engineering Record*, but two publishers and three chief editors. Of the present staff of ten technical editors, three have served for 35 years or more, and the terms of the next five in order of seniority are 22, 17, 15, 14 and 13 years.

In such long service, there is continuity of policy, and out of it spring comprehensive knowledge, sound judgment and journalistic competence.

That the labors of these 50 years have been crowned with a measure of success the publishers must recognize. From every side have come congratulations on the completion of the half century mark and expressions of appreciation of what *Engineering News-Record* has done for engineering and construction and for the men engaged in those callings.

For the help and encouragement which have made possible the accomplishments of these fruitful years, the publishers are profoundly grateful. If they and the editors have worked earnestly and sincerely, they have been more than heartily supported by the men it was their privilege to serve. Technical journalism is, in fact, a broad co-operative enterprise, in which the field supplies information to the publisher and the publisher, in turn, disseminates it to the field. We can not imagine this co-operative enterprise being worked out more happily than it has on *Engineering News-Record*. In this happy relationship we take an immense and justifiable pride and express to all who have worked in it, both within and without the organization, our profound gratitude.

We turn to the future with hope and with confidence. This great country will continue to develop, and at an accelerating pace. The demands upon civil engineering and construction will grow constantly greater. The field for *Engineering News-Record* will be richer than in the past.

We believe that adherence to the high principles that have brought the paper to this crowning anniversary issue, will be equally valid in the future. We pledge our organization anew to the policies of the past—a constantly improving service, greater helpfulness year after year, and an editorial policy dedicated to the service of the sound interests of readers.

Mr. Mehren writes here for the publishers of *Engineering News-Record*. Most readers need not be reminded that for twelve years he was the editor of *Engineering Record* (1912-17) and of *Engineering News-Record* (1917-23), and that as such he not only carried on the torch handed him by his predecessors but in his turn passed it along with brighter glow.—THE EDITOR.

Four full-page plates accompany this issue

The first is the lithograph of the Miraflores Lock of the Panama Canal under construction by Joseph Pennell. In his book on the canal Mr. Pennell says that he considers this the most artistic composition he found on the Isthmus. Engineers will admire it not only for its artistic qualities but for its faithful reproduction of the atmosphere of a large construction operation.

The second plate is from a photograph of the Tunkhannock viaduct on the Lackawanna R.R. furnished by George J. Ray, chief engineer of that road. This viaduct is one of the largest concrete structures in the world and is located on the latest cut-off on the Lackawanna between Scranton and Binghamton.

The third plate is taken from a copy of Diderot's Encyclopedia, published in France in 1770. The copy is in the possession of Daniel E. Moran, who writes the article on Foundations in this issue.

The fourth plate is a series of curves prepared by *Engineering News-Record* largely from original sources. It gives for the first time a 50-year continuous record of the progress of wages and prices.

APR 21 1924

Devoted to Civil Engineering and Contracting

McGraw-Hill Company, Inc.

Engineering News-Record

April 17, 1924

In Two Sections

News of the Week and Construction News

Section Two

NEWS OF THE WEEK

Reclamation Advisers Render Report

Praise Engineering And Administration —Part of Investment Not Repayable —Relief Measures Recommended

Reporting to the Department of the Interior on April 11, after six months' exhaustive study of reclamation of arid lands, the committee of special advisers appointed last summer has presented a full analysis of the status and difficulties of Western land reclamation, and recommends means by which these difficulties may be overcome. The report covers the past conduct of work under the Reclamation Act, complaints against cost and operation, and weaknesses of the present system. It ascribes many of the troubles to poor soil and market conditions, failure to select settlers fit for irrigation farming, speculation in land, and lack of provision for financing and aiding the farmer. It outlines the requirements that must be incorporated in law to make future reclamation successful. It fixes in detail the relief measures which should be applied to the present projects.

The special advisers praise the engineering administration highly, and do not support or justify the action of Secretary Work in uprooting the Reclamation Service and injecting political management. They state that the reclamation farmers have taken the attitude of being government wards, entitled to peculiar favor. Operation of the projects by the water users is set down as a primary requisite of reform. The difficulties in which the existing projects are involved find due recognition, however, in relief recommendations based on full consideration of the conditions prevailing on the projects.

On account of the great bulk of the report only a short summary has been made public. It is expected that the entire document will be printed by Congress.

Vital faults inhere in the existing law as related to present conditions, say the advisers. "The old pioneer settlement with its primitive farming is impossible under present conditions. Capital, technical knowledge, credit, and technical advice are all needed to make farming profitable under these costly projects. The farmers' needs must be kept in mind in rewriting the act if federal reclamation is to succeed."

In the existing projects, "numerous minor causes of distress will be found, but if (1) the lands of the projects are scientifically studied, classified and valued, (2) aid and direction are given in agricultural development, (3) the project management is assumed by the water users, and (4) a scientific and adequate plan of repayment is adopted,

(*Continued on p. 709*)

Railway to Build 332-Mile Line

The Interstate Commerce Commission on March 25 authorized the construction of the North & South Ry. from Miles City, Mont., to Casper, Wyo., a distance of 332 miles.

A considerable portion of this railroad has already been constructed as two separate intrastate railway lines under separate charters from Montana and Wyoming. The new line will serve the oil fields of the Salt Creek district, the timber area of the North Cheyenne Indian Reservation, and the great semi-bituminous coal fields of Wyoming and southern Montana.

Supreme Court Fails to Sustain California R.R. Commission

The California State Railroad Commission has no authority to order interstate railroads to construct a new passenger station at Los Angeles according to a decision of the United States Supreme Court, rendered on April 7, upholding a ruling of the California State Supreme Court. According to the U. S. Supreme Court, this authority is vested in the Interstate Commerce Commission by the Transportation Act of 1920.

The California Railroad Commission recently directed the Southern Pacific, the Santa Fe, and the Los Angeles & Salt Lake Railroads to construct a new union station at Los Angeles to cost from $25,000,000 to $40,000,000.

Am. Soc. C. E. Convenes at Atlanta

Power Economics and Interconnection, Highway Maintenance and Water Filtration Discussed

Engineering News-Record Staff Report

With an attendance of some 400, of whom nearly half were from distant points, the American Society of Civil Engineers held a highly successful meeting at Atlanta, Ga., April 9-12. The social intercourse side of the meeting was outstanding, and gave a lively reminder of former convention days. A short but interesting series of technical sessions and a conference of representatives of local sections formed the main part of the meeting April 9 and 10. Thereafter, the society left Atlanta for Tallulah Falls, 100 miles Northeast, where the Georgia Railway and Power Co. showed the party its extensive hydro-electric power developments on the Tallulah and Tugalo Rivers. In spite of some rain and mud this excursion was greatly enjoyed.

As noted last week, the Board of Direction took some important action in its session just preceding the meeting. It adopted a resolution of commendation for the appointment of Dr. Elwood Mead as Commissioner of Reclamation, a resolution asking Congress to delay action on the sale of the Muscle Shoals power plant until the full facts of the matter can be determined, and a resolution urging that all river and harbor work of the government be placed under civilian direction. It also established an annual conference of local sections and passed rules for the conduct of this conference. It approved a petition for the formation of a structural division, authorized the formation of student chapters at the University of Utah and Washington State College, and elected Charles H. Paul a director in place of R. N. Begien, resigned. It appointed a ways and means committee to raise additional funds for research. It also re-elected John H. Dunlap secretary of the society.

Military vs. civilian conduct of construction work came before the Board

not only through the resolution on river and harbor work, but also through a special report of the Board's committee on public relations, which cited and denounced certain statements recently made before the joint congressional committee on reorganization of departments by General Lansing H. Beach, Chief of Engineers, and Col. C. O. Sherrill, Corps of Engineers. These statements referred to "tremendous waste and graft" connected with the wartime construction for the army and charged this waste to the civilian management of the construction, as well as to the cost-plus system of contracting. The report to the Board of Direction pointed out the falsity of some of the allegations, expressed amazement at the character of the attacks, and recommended that the Board should not allow the charges to go unchallenged. The Board ordered that a copy of the report be forwarded to the two officers named.

The resolution favoring civilian control of river and harbor work declares that the Board of Direction "based on a knowledge of engineering projects covering many years denies the allegations that civilian engineers are incapable or extravagant, as is evidenced by their employment in all state, municipal and private work; and in the best interest of the people of the United States, strongly urges that all river and harbor work, including that of the Mississippi River Commission, and all other non-military engineering activities of the federal government should be under civilian and not under military engineering direction.

Muscle Shoals Resolution

The text of the Muscle Shoals resolution is:

"WHEREAS, the United States is expending many millions of dollars at Muscle Shoals on the Tennessee River for the purposes of manufacturing nitrates for ammunition and fertilizer, for the development of hydro-electric power and the relatively unimportant improvement of navigation, and

"WHEREAS, it is now proposed that a large part of these premises and structures be sold, or alienated from direct government control, and that these power projects be leased under conditions at variance with the provisions of the Federal Water Power Act, which act now governs all similar developments, and

"WHEREAS, we believe that there is widespread lack of reliable information concerning the conditions and lack of economy under which the work is being carried on, and much misinformation concerning the amount of dependable hydro-electric power that can be furnished, and

"WHEREAS, the present status of fixation of nitrogen for fertilizer and for ammunition by catalysis and chemical action under heat and pressure rather than by direct application of electric energy is little understood, all of which information we believe can be promptly obtained;

"THEREFORE BE IT RESOLVED, That the Board of Direction of the American Society of Civil Engineers assembled in regular meeting earnestly recommends that Congress take no action to lease or dispose of these properties until the above mentioned facts and the probable cost of fertilizer manufactured at Muscle Shoals in comparison with that produced elsewhere and any other information deemed pertinent have been determined and made plain by a fact-finding commission composed of eminent engineers and chemists and other men familiar with the manufacture, sale and commercial distribution on a large scale of nitrates and fertilizers, and be it

"FURTHER RESOLVED, That the Board of Direction of the American Society of Civil Engineers earnestly recommends that Congress enact no legislation to govern this project differing from the Federal Water Power Act, which governs all similar developments, or failing to permit full opportunity for presentation of plans by which the United States shall, within the shortest practicable time, recover substantially the cost of the structures built and required to be built for full development of these projects or, in lieu thereof lease the same under terms which will give an annual return proportional to the investment, and be it

"FURTHER RESOLVED, That the Board of Direction of the American Society of Civil Engineers believes that any awards for the sale or lease of these great projects should be made under the most open competition and in such form as will prevent unbalanced bidding and lack of opportunity of fair comparison of proposals."

Besides approving these resolutions of the Board, the society voted to adopt the final draft of specifications for highway bridges presented by the committee on bridge specifications and authorized their submission to the American Engineering Standards Committee.

Conference of Local Sections

In the session of the conference of local sections, with fourteen sections represented, discussion of the rules of procedure formulated by the Board of Direction showed much opposition to these rules, especially to the rules providing for only one meeting a year and naming the officers of the society as officers of the conference. Last January the conference itself framed rules of procedure providing for four meetings a year and for the election of officers by the conference. The Atlanta session of the conference voted eight to three to ask the Board to consider amending its rules in conformity with the rules previously formed by the conference.

At the two general sessions of the society, held April 9, papers were read by Prof. D. W. Mead, of Madison, Wis., on "Economics of Hydro-Electric Development" and by W. R. Cole, president of the Nashville, Chattanooga and St. Louis Ry., Nashville, on "The Railroads and Industrial Development of the South." The latter formed a strong plea for refraining from additional railroad legislation now, in order to let the Transportation Act of 1920 prove its worth, or the opposite. Mr. Cole particulary criticized various proposals contained in a large number of railroad bills now before Congress, to repeal the fair return clause of the law, to reduce rates on agricultural products and the like. Referring to the proposal to reduce the valuation of the carriers by one-third from the tentative figure set by the Interstate Commerce Commission, he showed that this would be of negligible influence on rates, as fixed charges are only 15 per cent of gross revenue. His views were supported in discussion by J. E. Willoughby, Hunter McDonald and F. H. McDonald. Professor Mead's paper was discussed by H. A. Hageman, C. B. Hawley and W. S. Lee. A closely-related paper was read on the following day at the power session by Charles G. Adsit, executive engineer of the Georgia Railway and Power Co., on "Operation of the Interconnected Power Systems of the South" which was discussed by Joseph Hyde Pratt, W. P. Hammond and E. A. Yates.

Road maintenance was discussed by the highway division almost exclusively with relation to earth roads. W. R. Neel, highway engineer of Georgia, read a paper "Highway Maintenance Costs and Problems," outlining the organization for maintenance and patrol in his state. Discussions by H. K. Bishop, W. S. Keller and C. H. Moorefield supplemented it by remarks on the experience of the Bureau of Public Roads and of the Alabama and South Carolina highway departments.

In the session of the sanitary engineering division Paul H. Norcross, of Atlanta, described the city's new filter plant.

Entertainment

The social features of the meeting, planned and carried out with characteristic Southern hospitality, were brilliantly successful. They included, besides a dinner to the Board of Direction, entertainment evenings to the society at the Piedmont Driving Club and the Eastlake Country Club.

Much separate entertainment was provided for the ladies of the party. The entire party was also taken out to see the stupendous enterprise of Gutzon Borglum, at Stone Mountain, where he is carving a Confederate war memorial bas-relief on a gigantic scale in the face of a 1000-ft. cliff. Mr. Borglum in person explained his optical projection method of marking the outlines of the figures on the cliff.

On the Tallulah Falls excursion the Georgia Railway and Power Co. displayed a hospitality and courtesy equal to that of the Atlanta engineers. The visiting party saw the 100,000-hp., 608-ft. development at Tallulah Falls, the lower head development at Tugalo a mile below, the Sawtooth tunnel construction some miles upstream, the Mathis hollow dam from which this tunnel will take its supply, and the new Yonah development farther down on the Tugalo.

L. I. to Electrify Montauk Line

The Long Island R.R. has announced that it will electrify its Montauk Division from Jamaica to Babylon at a cost of approximately $4,000,000. It will also electrify the freight line from Bay Ridge, Brooklyn, to Fresh Pond, where connection is made with the New York Connecting R.R. Other new construction includes two new stations, considerable grade-crossing elimination, new shop facilities, and extensions to existing freight yards.

Reclamation Advisers Report

(*Concluded from p. 707*)

all other elements of project discord and difficulty become of relatively slight importance."

After emphasizing the unquestioned financial integrity and the zeal and engineering skill of the Service, the committee brings out that agricultural deficiencies, slowness of settlement, soil difficulties, and similar influences have had a serious effect on the value of the nation's reclamation investment. "Large losses, running into millions of dollars, will have to be assumed by the reclamation fund." The definite or irrecoverable loss is computed at $18,500,000, and the additional probable loss at $8,830,000, a total of $27,330,000. The largest losses in this total are assigned to the Newlands, Milk River, Shoshone and Yuma projects, with three to four millions of loss on each. The losses represent items of the total cost of investigation and construction and unpaid installments of operation and maintenance charges whose repayment "it is not just to require, and in some instances not possible to obtain." A number of projects show no loss, among them Orland, Minidoka, Boise, Carlsbad, Rio Grande, Strawberry Valley, and Yakima.

Reclamation Declared Success

Despite this financial result, the report declares reclamation a success: "During the last few years these projects have produced annually, on about 1,200,000 acres, crops valued at 50 to 75 millions of dollars. Besides, 1,101,700 acres of land are receiving a partial water supply under the terms of the Warren Act from the Federal irrigation projects and are producing greatly increased crops therefrom. Thousands of happy families are growing up in the open country under influences that have always fashioned men and women of strength. Moreover, these projects have helped in the conquest, for human good, of the more difficult places of our country, and thereby have shown the great value of the arid and semi-arid region."

Three basic recommendations are made for the existing projects, aside from water users' operation and specific cost reductions and other relief for the several projects which will be noted later. These three are, (1) that the law requiring repayment in fixed installments be changed so as to base repayment on the average productivity of the project, the annual repayment to be 5 per cent of the average gross crops over a period of years: (2) that lands on each project be classified as to value and the repayment proportioned to the values so determined; and (3) that a credit system be established by the government to finance the farmer's improvements and equipment, on long-term repayment, with interest.

Future reclamation, in the committee's opinion, should include the following fundamentals:

(a) That no project be authorized until all private land in excess of a single homestead unit for each owner shall have been purchased by the United States or placed under contract for subdivision and sale;

(b) that applicants for farms be examined, and only those having reasonable prospects of succeeding be allowed to settle;

(c) that land leveling and water distribution be done as part of the project construction; and

(d) that no project be authorized except on favorable report by the Interior, Agriculture and Commerce departments on the feasibility of the project (or extension), "having in mind primarily the creation of opportunities for actual settlement and farm homes and the repaying of the total investment made by the government."

Of the extensions and new projects now under consideration the committee recommends construction of the Guernsey reservoir, North Platte project; the Spanish Springs reservoir, Newlands project; the Owyhee and Vale projects, Oregon; the Kittitas project, Washington; and the Salt Lake Basin project, Utah. As to the last four, the recommendation is contingent upon further proof of their feasibility and upon application of the new principles set out to govern future reclamation.

A fuller abstract of the report will be given in next week's issue. The board of special advisers consists of ex-governor Thos. E. Campbell, of Arizona; chairman; Dr. John A. Widtsoe, of Utah, secretary; James R. Garfield, of Ohio, former Secretary of the Interior; Dr. Elwood Mead, of California; Oscar Bradfute, of Ohio; and Clyde C. Dawson, of Colorado. Its report is unanimous.

New Plan Saves High Bridge

Plans for remodeling High Bridge across the Harlem River, New York City, which were worked out by engineers of the Department of Plant and Structures together with a group of leading architects and engineers of the city who led the fight to avoid demolition of the historic structure, have been approved by the Municipal Art Commission. More than a year ago the Board of Estimate had voted to raze High Bridge, substituting an inverted siphon to carry the waters of the Croton Aqueduct which the bridge had carried. Protest against destruction, and the suggestion by engineers, architects and artists of a new plan for reconstructing the bridge to meet navigation requirements, led to abandonment of the original plan to raze the bridge.

Los Angeles Sewage Screening Plant Completed

The new sewage screening plant at Hyperion, near Los Angeles, was tested out for the first time on April 1. The plant was not put in permanent operation, pending the completion of the structure housing the screening units and the arrival of some of the mechanical equipment whose delivery has been delayed. Operation on a permanent basis will commence about May 1, using the eight Dorrco screening units, each of which has a capacity of 416,000 gal. per hour. The full capacity of the plant will thus be 10 m.g.d. Provision is made for additional capacity at a later date.

Indianapolis Plans Extensive Flood-Prevention Work

A resolution setting aside $3,150,000 of flood prevention work on White river between Washington St. and Morris St., Indianapolis, has been confirmed by the board of public works and bids will be obtained in a few weeks. The resolution provides for widening the stream, erecting new bridges at Kentucky and Oliver Avenues, and extending the flood wall. It is the first of three flood-prevention resolutions planned by the board of works. The two bridges will be erected first. It is estimated the Kentucky Ave. bridge will cost $723,000 and the Oliver Ave. bridge $493,000.

A.E.C. to Report on Muscle Shoals

In compliance with a request from Senator Norris, the chairman of the Senate Agricultural Committee, the American Engineering Council has chosen a committee to make a report on the disposition of the government's Muscle Shoals properties. The committee is composed of F. R. Low, New York, president American Society Mechanical Engineers; H. E. Howe, Washington, American Chemical Society; J. B. Davidson, University of Iowa, agricultural engineer; H. B. Walker, Agricultural and Mechanical College of Kansas, agricultural engineer; P. N. Moore, St. Louis, mining engineer; E. B. Whitman, Baltimore, chairman Maryland Public Utilities Commission; H. W. Buck, New York, electrical engineer; Dr. Leonard Waldo, New York, mining engineer. The committee held its first meeting in Washington April 15.

Quarterly Meeting Accomplishments of A.A.E. Directors

A 50 per cent increase of reserve fund with a total of $16,000 was reported to the board of directors of the American Association of Engineers at its recent quarterly meeting. Dues were adjusted during the year to April 1 from the anniversary of the date members joined. This resulted in cutting the income to nearly one-half of that of a normal year.

Charters were granted to Stockton and Santa Barbara, Calif., and Rose Polytechnic Institute at Terre Haute, Ind. The New Orleans chapter and the North Carolina Division were given Class A designation and will, after April 1, collect dues, maintain a business office and render employment service. The Chicago chapter was placed in escrow, the charter to be revoked unless it surrenders its state charter of incorporation, which is not provided for or countenanced by the national body, and unless it otherwise recognizes the suzerainty of the national board of directors.

The insurance committee presented a report of satisfactory progress with an old line company for favorable rates for term, straight life, twenty-year life and endowment policies to members of the association. The report also gave the amount of capital and rates necessary to form an independent company.

Engineering Societies

Calendar

Annual Meetings

NATIONAL FIRE PROTECTION ASSOCIATION, Boston, Mass.; Annual Meeting, Atlantic City, N. J., May 13-15, 1924.

AMERICAN WATER WORKS ASSOCIATION, New York City; Annual Convention, New York City, May 19-24, 1924.

AMERICAN ASSOCIATION OF ENGINEERS, Chicago, Ill.; Annual Meeting, San Francisco, Calif., June 11-13, 1924.

AMERICAN SOCIETY OF CIVIL ENGINEERS, New York City; Annual Convention, June 18-20, Pasadena, Calif.

AMERICAN SOCIETY FOR TESTING MATERIALS, Philadelphia, Pa.; Annual Meeting, Atlantic City, N. J., June 23-28, 1924.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, University of Pittsburgh; Annual Meeting, Boulder, Colo., June 25-28.

The Harvard Engineering Society at its annual meeting April 10 elected the following officers: President, Robert Ridgway, New York City, chief engineer, New York Transit Commission; vice-presidents, Harry E. Clifford, Cambridge, Mass., and William L. Hanavan, Newark, N. J.; secretary, Theodore R. Kendall, engineering editor, *The American City*, New York City; and treasurer, Edric B. Smith, New York City.

Personal Notes

Dr. D. B. STEINMAN, consulting engineer, has returned to his New York office after a four-months' trip to Australia in connection with the Sydney Harbor bridge.

F. J. HERLIHY, formerly with the White Paving Co., Chicago, has organized the Mid-Continent Construction Co., specializing in heavy construction including sewage disposal systems, water filtration plants, grade separation work for railroads, etc. Mr. Herlihy is president and M. H. FINLEY vice-president of the new company.

T. P. O'NEILL has been appointed assistant engineer, maintenance-of-way of the Chicago, Burlington & Quincy R.R., to succeed H. C. Murphy. Mr. O'Neill's headquarters will be at Alliance, Neb.

C. H. GRIGGS has been appointed a division engineer on the Buffalo, Rochester & Pittsburgh Ry., with headquarters at East Salamanca, N. Y., vice F. A. BENZ, resigned to engage in business.

H. P. MCKEAN has resigned his position as engineer in the office of O. B. Coldwell, vice-president of the Portland, Ore., Railway, Light & Power Co., to accept a position with L. F. Harza, consulting engineer, Monadnock Bldg., Chicago, Ill.

B. MORRIS HOOPER, formerly engineer on industrial plant design and on appraisal work with H. M. Haven & A. T. Hopkins, Inc., of Boston, is now engineer in the mechanical division of Stone & Webster, Inc., of Boston.

GUSTAVE LIMA, assistant engineer in the New York State Highway Department, and secretary of the division office at Utica, N. Y., sails soon to take a position with the Chile Exploration Co., South American branch of the Anaconda Copper Co. Mr. Lima is a native of Puerto Rico and an engineering graduate of Cornell University.

L. C. SMALLWOOD CONTRACTING CO., Chattanooga, Tenn., engineers and constructors and specialists in concrete designs and erection, announce the association of Clifford A. Betts with the company. Mr. Betts is a consulting engineer of Chattanooga.

C. H. MOTTIER, office engineer of the Chicago Terminal Improvement organization of the Illinois Central R.R. at Chicago, has had his title changed to engineer of design.

C. C. FISHER, engineer, Bureau of Reclamation, in charge of investigations in southern Colorado on the San Juan Basin, has been sent to St. Croix Island of the Virgin Island group at the request of the Navy Department to study the possibilities of an irrigation project on the island.

NAGLE, WITT & ROLLINS, consulting engineers of Dallas, Tex., have opened a branch office in Houston in the Keystone Bldg. with Andrew P. Rollins as branch manager. This firm is retained by Dallas County as engineers in charge of highway work and by the city of Port Arthur in making numerous paving and sewerage improvements.

U. G. JACKSON, city engineer of Kelso, Wash., for three and a half-years, has resigned to enter private practice.

H. E. SNOW, recently assistant engineer for the city of Fort Worth, is now assistant engineer for La Feria, Texas, Water Improvement District No. 1 on irrigation projects for which plans are in progress. Mr. Snow was formerly city engineer of Brownsville.

CARROLL E. THOMPSON, formerly assistant director of the Department of Wharves, Docks, and Ferries of the city of Philadelphia, has been appointed chief engineer of the department. Mr. Thompson assumed his new duties shortly before the present city administration took office.

BRUCE VERNON, formerly assistant chief engineer and later consulting engineer for the Montreal Tramways Co., is now engineer in the structural division of Stone & Webster, Inc., of Boston, Mass.

GEORGE D. SCHEUNEMAN, formerly assistant division engineer, Ohio State Highway Department, has joined the sales force of the Blaw-Knox Co., Pittsburgh, manufacturer of concrete construction equipment and other steel products. He will serve in the company's road department, with offices in the Peoples Gas Building, Chicago.

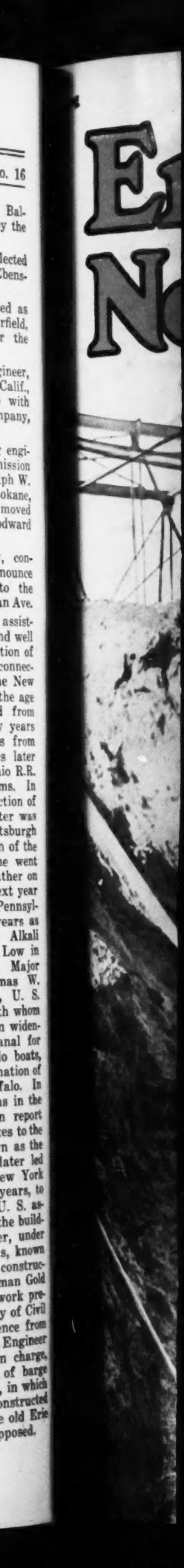
JOHN M. RUSSELL has been appointed structural engineer in the Municipal Building Inspector's Department, Baltimore, filling a vacancy caused by the resignation of J. H. Stehl.

SAMUEL E. MAY has been elected engineer for the borough of Ebensburg, Pa.

E. W. HESS has been re-elected as engineer for the borough of Clearfield, Pa., assuming the position for the eighteenth successive year.

B. F. JAKOBSEN, consulting engineer, has closed his offices at Fresno, Calif., and entered into a partnership with the Duncanson Harrelson Company, contractors, San Francisco.

WILLIAM H. ADAMS, consulting engineer, Detroit, announces the admission to partnership of his brother, Ralph W. Adams, structural engineer, Spokane, Wash. Their offices have been moved to 504 Hofman Building, Woodward Ave., at Sibley.

PEARSE, GREELEY & HANSEN, consulting engineers, Chicago, announce the removal of their offices to the Tower Building, 6 North Michigan Ave.

EMILE LOW, since 1907 U. S. assistant engineer at Buffalo, N. Y., and well known for his work on construction of the Buffalo breakwater and his connection with the early plans for the New York Barge Canal, on reaching the age of seventy on April 2 retired from active service. Mr. Low's early years were spent in railroad surveys from Pittsburgh to Virginia on lines later absorbed by the Baltimore & Ohio R.R. or the Pennsylvania R.R. systems. In 1871 he made a survey of a section of the Monongahela River, and later was chief engineer of the new Pittsburgh water-works and on construction of the Highland reservoir. In 1881 he went to Mexico as assistant to his father on the Mexican Central Ry. but next year returned to railroad work in Pennsylvania. After spending four years as engineer of the Mathieson Alkali Works at Saltville, Va., Mr. Low in 1896 became associated with Major (now Colonel, retired) Thomas W. Symons, Corps of Engineers, U. S. Army, stationed at Buffalo, with whom he prepared in 1896 a report on widening the locks in the Erie Canal for the passage of modern torpedo boats, having made a complete examination of the Canal from Albany to Buffalo. In 1897 he assisted Major Symons in the preparation of his well-known report for a canal from the Great Lakes to the Hudson River, generally known as the Barge Canal Report, which later led to the authorization of the New York Barge Canal. The next six years, to 1903, Mr. Low was resident U. S. assistant engineer, in charge of the building of the Buffalo breakwater, under the direction of Major Symons, known for its special rubble mound construction, and he received the Norman Gold Medal for his paper on this work presented to the American Society of Civil Engineers. On leave of absence from 1904 to 1907 from the U. S. Engineer Department, Mr. Low was in charge, for the state of New York, of barge canal work in Oneida County, in which a new section of canal was constructed in preference to widening the old Erie Canal, which Mr. Low had opposed.